CRREL'S FIRST 25 YEARS

1961-1986

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PREFACE

This commemorative booklet incorporates much of the material and personal reflections that have been assembled over the years for use in preparing the history of CRREL. Thus, *CRREL's First 25 Years* should not be confused with the official history, which should be available soon.

This booklet was prepared by Edmund A. Wright, Technical Publications Writer-Editor, Technical Information Branch, Technical Services Division, U.S. Army Cold Regions Research and Engineering Laboratory.

CRREL CHRONOLOGY

1944 - Frost Effects Laboratory established in Boston, Massachusetts, within the New England Division, Corps of Engineers, to coordinate research on the effects of frost on the design and construction of roads, airfields and structures in frost-affected areas.

1945 - The Permafrost Division of the St. Paul (Minnesota) District, Corps of Engineers, established to determine design methods and construction procedures to be used in the construction of airfields on permanently frozen ground.

1949 SIPRE (the Snow, Ice and Permafrost Research Establishment) established within Corps to conduct basic and applied research in snow, ice and frozen ground.

1951 - SIPRE moves to Wilmette, Illinois.

1953 - ACFEL established in Boston by combining Frost Effects Laboratory and Permafrost Division of the St. Paul District.

1959 - Camp Century in Greenland is first occupied.

1961 - CRREL established (on 1 Feb 1961) in Hanover, New Hampshire, by combining SIPRE and ACFEL, Colonel William Nungesser is appointed Commanding Officer.

1962 - Fire causes extensive damage to main laboratory building at CRREL during construction. CRREL transferred from Corps of Engineers to the Army Materiel Command. W. Keith Boyd becomes first Technical Director.

1963 - Laboratory fully operational; first open house, 22-24 November.

1964 - Colonel Philip Krueger succeeds Colonel Nungesser.

1966 - Colonel Dmitri Kellogg succeeds Colonel Krueger.

1967 - Colonel John Wagner succeeds Colonel Kellogg.

1968 - CRREL redesignated U.S. Army Terrestrial Sciences Center (TSC). CRREL drillers accomplish first penetration of Greenland ice sheet. Facilities Engineering Building completed.

1969 - “TSC” reassigned to Corps of Engineers and CRREL designation is reassigned. CRREL drillers make first penetration of Antarctic ice sheet.

First voyage of *Manhattan.*

1970 - Lieutenant Colonel Joseph Castro succeeds Colonel Wagner. Second *Manhattan* voyage. Photographic Interpretation Research Division transferred to the Army Materiel Command.

1972 - Dr. Dean Freitag becomes Technical Director. Large anti-Vietnam War demonstrations staged at CRREL.

1973 - Colonel Robert Crosby succeeds Colonel Castro.

1974 - Alaskan Division reorganized as Alaskan Projects Office.

1976 - Logistics and Supply Building completed.

1977 - CRREL addition completed.

1978 - CRREL receives Army Special Award for Accomplishment; Ice Engineering Facility officially opened; Colonel Alfred Devereaux succeeds Colonel Crosby.

1979 - CRREL receives U.S. Army Award for Excellence. Ice Engineering Facility dedicated.

1981 - CRREL's 20th Birthday Celebration on 16 September. Colonel Wayne Hanson succeeds Colonel Devereaux.

1982 - Dr. Lloyd Breslau becomes Technical Director.

1983 - Colonel Morton Roth succeeds Colonel Hanson.

1985 - Frost Effects Research Facility completed and dedicated.

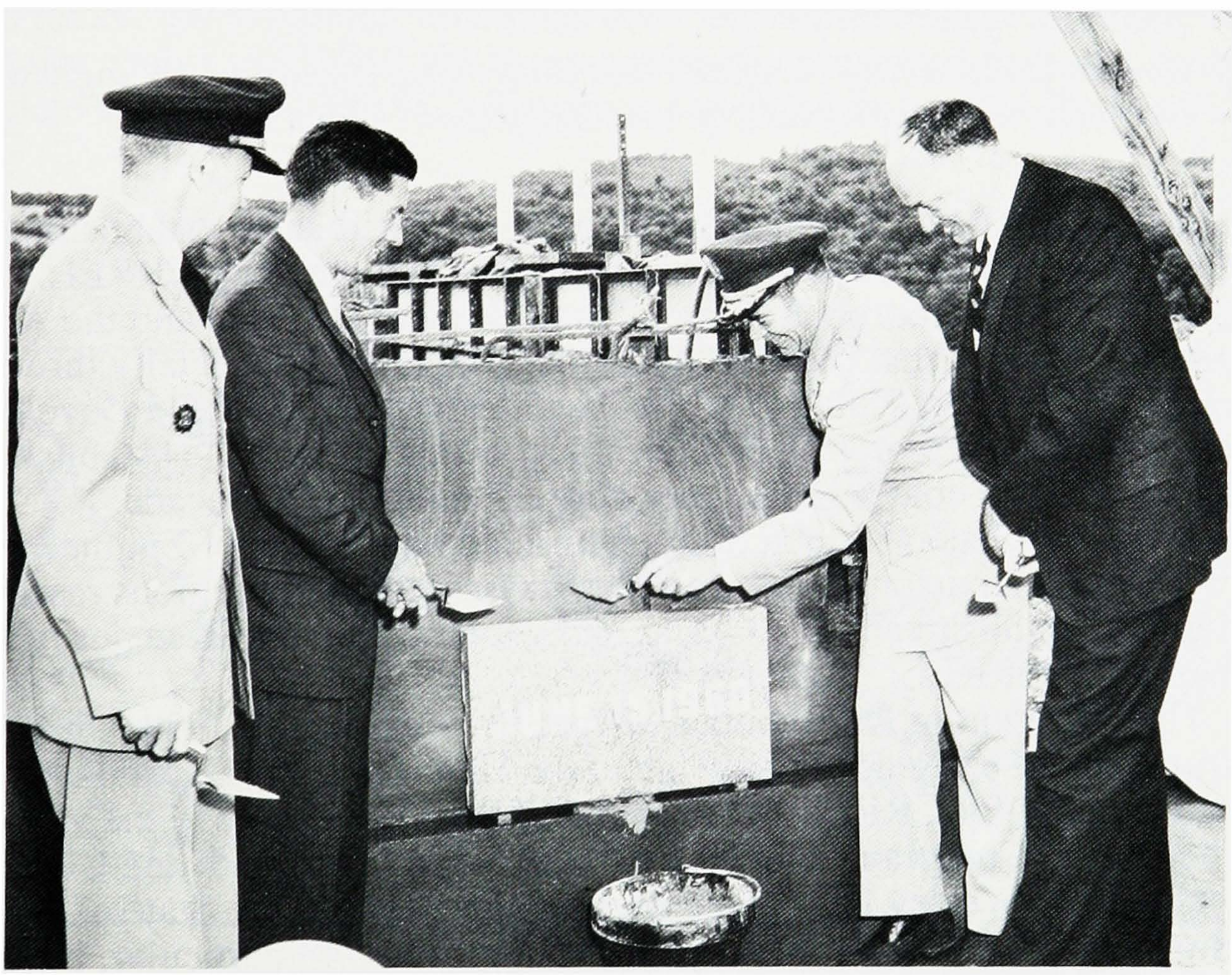
1986 - Dr. L.E. Link becomes Technical Director.

INTRODUCTION

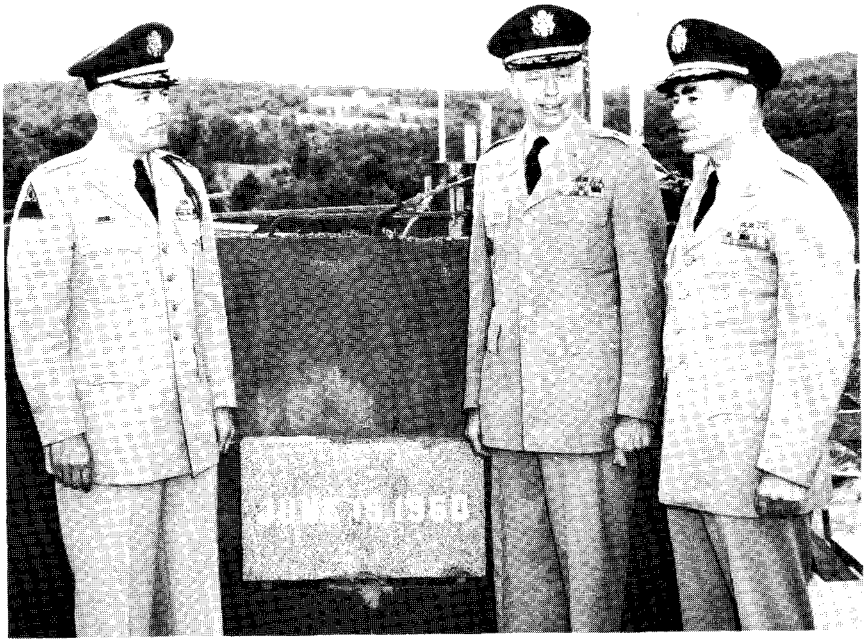
On the 15th of June 1960, a small group of individuals assembled on a tract of land about 1 1/2 miles north of Dartmouth College in Hanover, New Hampshire, to lay the cornerstone for a new research laboratory. Among them were Brigadier General Duncan Hallock, Chief, Research and Development Division, of the U.S. Army Corps of Engineers, Brigadier General Alden Sibley, Division Engineer of the New England Division, U.S. Army Corps of Engineers, Dr. John Sloan Dickey, President of Dartmouth College, and Wesley Powell, Governor of New Hampshire, Kenneth A. Linell, Director of the Arctic Construction and Frost Effects Laboratory, Colonel William Nungesser, Commanding Officer of the Snow, Ice and Permafrost Research Establishment.

These individuals had assembled to mark the beginning of construction of the Cold Regions Research and Engineering Laboratory, or CRREL, as it soon was to be known. And each of them represented the many forces that had come together to bring CRREL into existence.

Brigadier General Duncan Hallock represented the U.S. Army Corps of Engineers, which was, of course, the organization most directly involved in



Cornerstone laying ceremonies. L to R: Brig. Gen. Duncan Hallock, Chief, Research and Development Division, Office of the Chief of Engineers, Washington, D.C.; Gov. Wesley Powell, State of New Hampshire; Brig. Gen. Alden K. Sibley, Division Engineer, New England Division, U.S. Army Corps of Engineers; and Dr. John Sloan Dickey, President, Dartmouth College.



Cornerstone laying ceremonies. L to R: Col. William L. Nungesser, Brig. Gen. Duncan Hallock and Brig. Gen. Alden K. Sibley.

establishing CRREL. The Corps had been responsible for establishing and maintaining the two predecessor organizations that made up CRREL: the Snow, Ice and Permafrost Research Establishment (SIPRE) and the Arctic Construction and Frost Effects Laboratory (ACFEL). Especially through the efforts of Robert Philippe, of the Engineering Research and Development Division, the Corps of Engineers had been planning the establishment of a consolidated cold regions laboratory for more than a decade.

Brigadier General Alden Silby represented the Corps of Engineers' New England Division, which had been involved in cold regions research and in the establishment of ACFEL, and which would play a major role in constructing CRREL.

The President of Dartmouth College, Dr. John Sloan Dickey, had been instrumental in bringing the new lab to the Hanover area. Dartmouth had leased the land for CRREL to the Corps of Engineers and had the vision of the cooperative programs that now exist between Dartmouth and CRREL.

Governor Wesley Powell represented the effort by the State of New Hampshire to have the laboratory sited in Hanover. In particular, New Hampshire's U.S. Senate delegation, Senators Styles Bridges and Norris Cotton, had been instrumental in bringing CRREL to its present site.

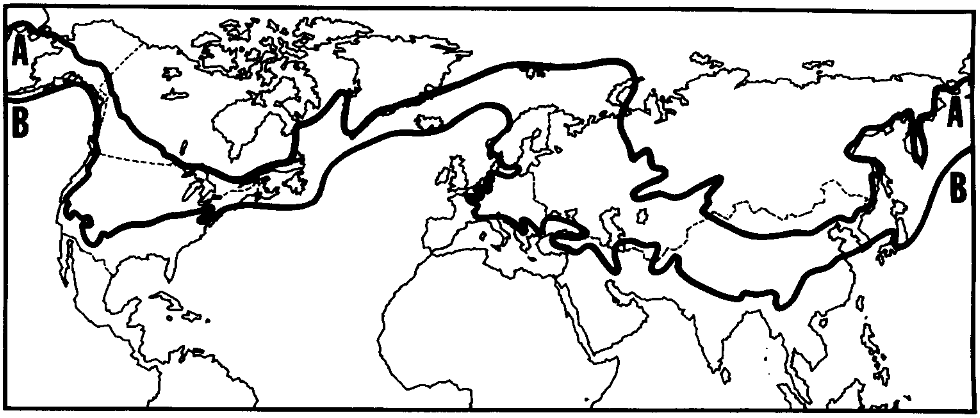
Colonel William Nungesser, Commanding Officer of SIPRE, represented the first Corps laboratory established to conduct research in the cold regions. SIPRE's role had involved both basic research and engineering, particularly in Greenland and Antarctica.

Kenneth Linell, the Director of ACFEL, was the head of the second of the two Corps of Engineers laboratories to be established for cold regions research. This laboratory, originally in Boston, and later in Waltham, Massachusetts, had pioneered much of the engineering work on frost action, permafrost, snow and ice in Alaska and on the Greenland Ice Cap.

All of these organizations and individuals assembled at this site to found a new laboratory that was to grow both in size and scientific reputation far beyond original projections. Soon after the groundbreaking ceremonies, even the name was changed to reflect the laboratory's enlarged role—from the Cold Regions Engineering Laboratory (CREL) to the Cold Regions Research and Engineering Laboratory. For the new laboratory was soon to gain a world-wide reputation not only for solving the problems of cold regions but also for investigating the basic characteristics of the cold regions environment.

Since 1963, when the main laboratory building was completed, the total space of the CRREL buildings has more than doubled, the annual budget for research has increased by an order of magnitude and the total staff has increased in number by more than 50%. And in both research capabilities and in reputation the increases have been enormous.

In the following pages is presented the story of the Cold Regions Research and Engineering Laboratory, from its predecessor organizations to its status today. Of necessity, much has been left unmentioned, but many of the major events in CRREL's history are briefly presented here. (A more complete account of CRREL's history is presented in Internal Report 917).



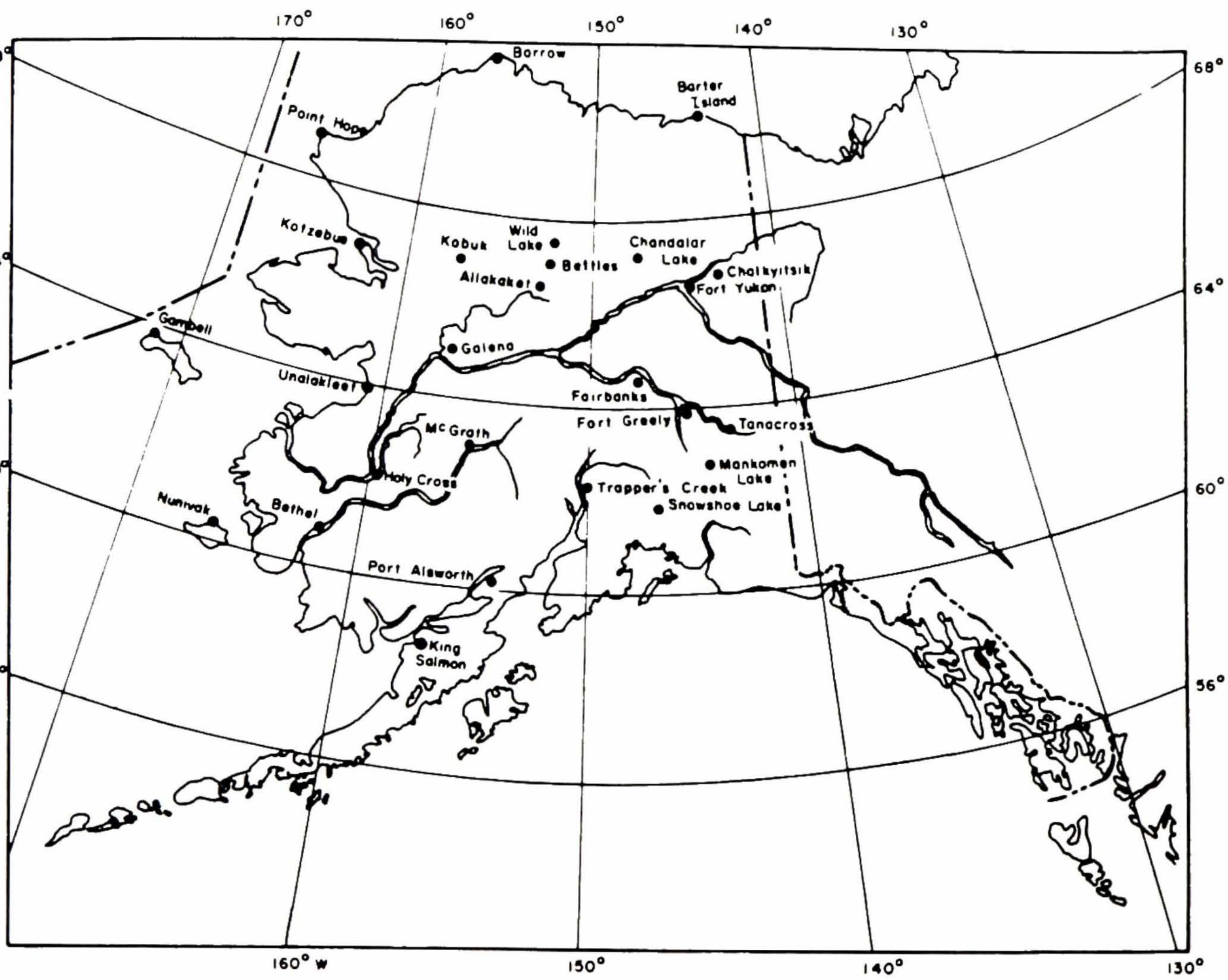
CRREL's mission in the cold regions of the Northern Hemisphere lies north of line B. (North of line A the approximate average temperature in the coldest month is 0°F; line A is also the approximate southern limit of discontinuous permafrost. North of line B the approximate average temperature in the coldest month is 32°F.)

ANTECEDENTS

In investigating the antecedents of CRREL, one must trace back through the early years of the cold regions construction activities of the Corps of Engineers, which has been involved in the exploration and development of Alaska since soon after its purchase from Russia in 1867. Explorers from the Corps surveyed the region, built the early trails that eventually became Alaska's major highways and established port facilities along much of Alaska's 5500 miles of coastline. It was not until World War II, however, that Corps construction activities in the cold regions expanded to major proportions.

Prior to U.S. involvement in World War II, the War Department recognized the strategic importance of Alaska and by early 1940 had developed a comprehensive plan for the development of a military establishment in Alaska. In 1941 the Department placed all military construction in Alaska under the control of the Corps of Engineers. In the next 2 years the Corps completed Ladd Field in Fairbanks, built Fort Richardson at Anchorage, and constructed airfields on the Aleutian Islands and posts at Kodiak, Dutch Harbor and Sitka.

Yet the most extraordinary project performed by the Corps in Alaska during this period was the construction of a road that established an all-land link between Alaska, Canada and the continental United States for the first



Alaska.

time. Soon after Pearl Harbor (in January 1942), President Roosevelt requested that the War and Interior Departments begin to study and make recommendations for an Alaskan military road to protect the territory from the Japanese. By March, plans had been drawn up for 1450-mile-long road from the railhead at Dawson Creek, Alberta, Canada, to Fairbanks, beginning perhaps the largest construction project undertaken by the Corps since the Panama Canal.

Over 10,000 workers, both military and civilian, completed this "Pioneer Road" through 1450 miles of wilderness in only 8 months. Personnel working on the road had to deal with extremely difficult conditions, involving tundra, permafrost, muskeg, and numerous streams and rivers. This road, later called the Alcan Highway, has since been greatly improved and now serves as an important route to Alaska.

On 7 and 8 June 1942, the completion of "The Burma Road of the North," as the Pioneer Road was then called, was given an additional impetus when the Japanese invaded and occupied Attu and Kiska Islands, far out on the Aleutian chain. This event also spurred efforts to develop landing strips to complement the Canadian airfields then under construction that stretched along the highway from Edmonton to Whitehorse. These, combined with six fields in Alaska (Northway, Tanacross, Big Delta, Ladd, Galena and Nome) constituted the U.S. air link with Alaska and the U.S.S.R. called the Northwest Staging Route. Although a principal role of the highway was to make possible the building and supplying of these airfields, pilots soon discovered that the road served an important function as a visual guide for these flights.

At the same time that the Alcan Highway was being built, the Corps was also constructing four connecting pipelines in Canada and Alaska totaling 1600 miles—twice the distance of the present trans-Alaska pipeline from Prudhoe Bay to Valdez. CANOL, as it was called, was to be a fuel supply backup for trucks on the Alcan Highway and planes using the Northwest Staging Route. In its first and only year of operation, 1,102,000 barrels of crude passed through from Norman Wells to Whitehorse.

The Permafrost Division and Alaska Field Station

The Permafrost Division was founded by the St. Paul District of the Corps following a Conference on Permafrost, held at St. Paul, Minnesota, in January 1945. The Office of the Chief of Engineers (OCE), had initiated the conference because of the problems that the Army Air Forces were experiencing with the airfields along the Alcan Highway and in Alaska.

The conferees concluded that a field station should be established in Alaska to coordinate the laboratory and research work performed there. The proposed base for this laboratory was Ladd Field (now Fort Wainwright, near Fairbanks) but securing space and proper facilities there was not possible at that time. The Permafrost Division chose Northway Airfield as their temporary field station in February 1945.

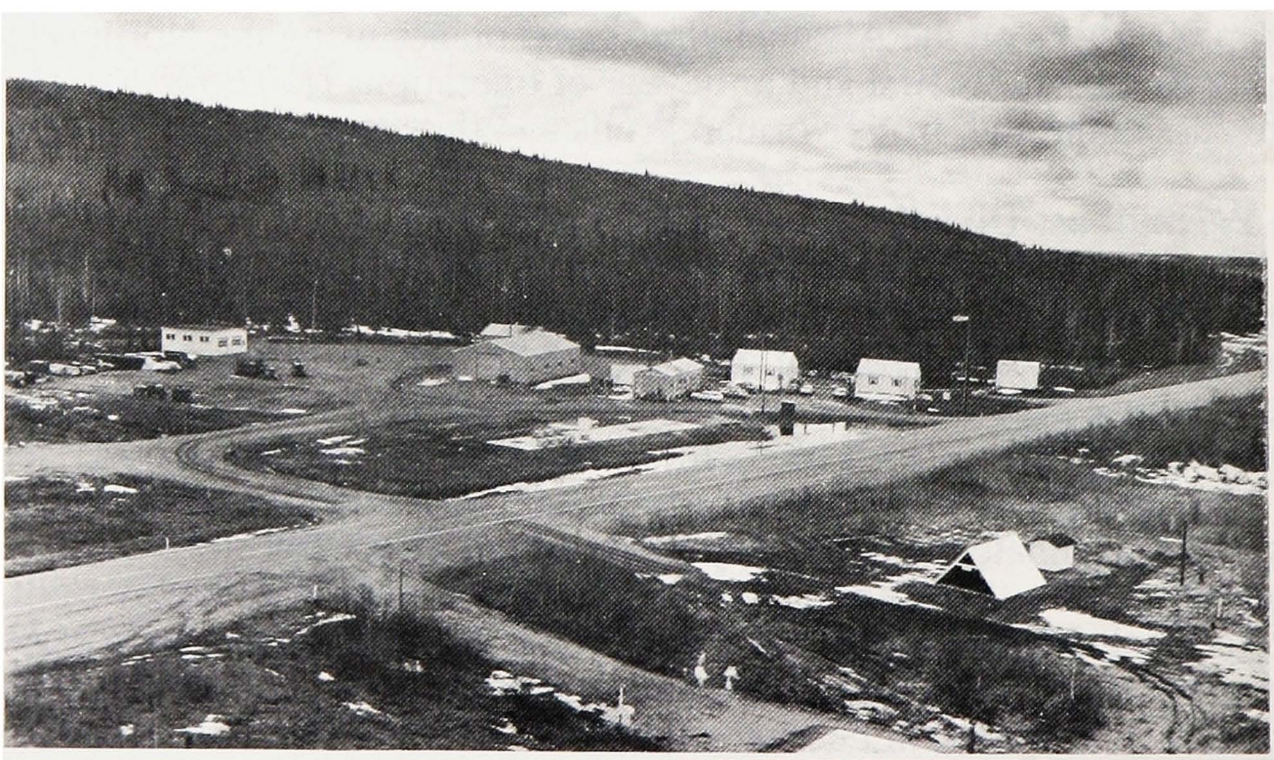
From that time on, most of the activities of the Permafrost Division of the St. Paul District were based in Alaska. The Alaskan unit consisted of four officers, 1 enlisted man, 6 engineers, 19 "staff" and 13 laborers. The

engineers began testing at Northway on 26 February 1945. In addition to observing and cataloging the stress factors on the structures and runways, they also constructed an experimental test area to obtain data on permafrost behavior. They found that thawing of the subsoil under the hanger at Northway had reached 25 ft after only 3 years and that the most stable structures were ones that were supported on sand and gravel fills and on piles embedded in the permafrost.

By September of 1945, the entire Field Operations Branch moved, with personnel and equipment, to Ladd Field, although they maintained their ongoing research at Northway until 1948. Many studies were conducted on facilities, such as barracks, the hospital and power plants. However, a field site with permanently frozen soils, typical of interior Alaska, was considered more desirable for detailed research. Accordingly, 135 acres of undisturbed ground on the Farmer's Loop Road, about 3 miles northeast of Fairbanks, was leased. While the experimental area has had several names over the years, its most common name was the Alaska Field Station.

Active construction of test facilities began in 1946 with the building of a weather station, the installation of ground temperature sensors and the establishment of test sections. Additional buildings with experimental foundations were also constructed in the mid-1950's and 1960's, including pile foundations, concrete rafts and ducted foundations. While these buildings provided office, laboratory, garage, storage and living quarters for the station, their instrumented foundations also provided valuable information on the long-term performance of each system on the relatively warm permafrost of this area.

Testing and research at the Alaska Field Station has continued to provide information on construction practices in the Far North now for nearly four decades.



Alaska Field Station.

Experimental foundations at Alaska Field Station.

Frost Effects Laboratory and ACFEL

In the early 1940's, a special soils laboratory was established on Commonwealth Avenue for the Boston District of the New England Division, Corps of Engineers. This laboratory pioneered soil testing experiments aimed at minimizing frost damage to runways. Soon OCE began to refer many of the early runway problems to this small laboratory of about a dozen engineers and draftsmen.

For about three years the laboratory operated as a department within the Soils Lab of the Boston District, but the demands from Washington for its specialized services increased and the Frost Effects Laboratory was established as a separate entity. There was also an increased demand for the services of the Frost Effects Laboratory from airfields in the northern continental United States (excluding Alaska, which fell under the newly established Permafrost Division's jurisdiction). The laboratory published its first Frost Effects Technical Manual in 1946; it was called "Pavement Design for Frost Conditions" (TM 5-818-2) and, having been constantly updated, is still in use by design engineers today. This manual was accompanied by a number of other Engineering Manuals on the design of roads and airfields subject to frost conditions.

In 1947, a research effort was begun on the Greenland Ice Cap. In the areas explored, Frost Effects Laboratory researchers found enormous areas of hard ice that could support very heavy supply aircraft on wheels. The researchers also found that weather conditions on the Ice Cap were no more severe than at some existing military land stations in northern North America.

Examining an ice core obtained with a CRREL auger.

After the early Greenland studies, the Frost Effects Laboratory received a number of assignments concerning the properties of snow, ice and seasonally frozen ground—whenever these natural phenomena affected the construction of buildings, roads, airstrips and foundations. Researchers from the lab soon constructed two coldrooms for their laboratory experiments.

In 1948 the laboratory went to work for the Hydrographic Office of the U.S. Navy, with, of course, authorization from OCE. The purpose of the project was to develop a portable ice mechanics test kit for boring holes in ice, obtaining ice cores and measuring the physical properties of ice in the field. The resulting Ice Mechanics Test Kit was soon used not only by the Navy, but also by the Woods Hole Oceanographic Institution, which had been carrying on some experiments with sea ice at Point Barrow, Alaska, in 1949. The kit contained the forerunner of a 3-in. CRREL ice auger, which has become a standard instrument for glaciology studies.

Both the Frost Effects Laboratory and the Permafrost Division of the St. Paul District had active roles to play in the construction of the airfield at Thule, Greenland, formerly a weather station and soon to become, in 1952, the northernmost Air Force Base. Such cooperation between the Frost Effects Laboratory and the Permafrost Division of St. Paul was on the increase when the two research organizations were merged. The merger seemed appropriate as the two organizations had been working together since 1950 and most personnel knew each other on a first-name basis. The merger became official on 25 February 1953 by OCE General Order No. 3

Project AT-43, Thule, Greenland. General view of Solo Expedition camp site after snow storm.

establishing the Arctic Construction and Frost Effects Laboratory (ACFEL). Two of the engineers from St. Paul moved to Boston to become part of the new organization. With the merger, ACFEL inherited the Alaska Field Station, at Fairbanks.

ACFEL conducted many studies during the early 1950's—most of which had a direct bearing on the subject of airfields. One study worthy of mention was entitled *Depth of Snow Cover in the Northern Hemisphere.* This study presented the average snow depths between 31 October and 31 May around the Earth's entire northern hemisphere, and cited thousands of stations as its reference points, with maps illustrating areas of varying snow depths.

In the spring of 1953, ACFEL was again called to Greenland because of the subsidence of some runway pavement sections during the previous summer. The ACFEL investigators found high ice-content soils in the test pits. They predicted further subsidence of 2 to $2^1/_2$ ft and recommended that the runways be dug up and relaid to ACFEL specifications, which they were.

In 1954, Camp TUTO was begun, in the lake area of the Ice Cap, 14 miles southeast of Thule, to serve as a rendezvous and research base for scientific exploration of the Ice Cap. But getting to the site from Thule with supplies and heavy construction equipment presented a difficult problem. Roads had to be built through the bouldery permafrost terrain and over the glacial ice. ACFEL engineers found it not only feasible to construct and maintain military gravel roads on the Greenland Ice Cap, but also concluded

Height of fill on ramp road, August 1955.

Start of first 1958 swing.

Aerial view of Camp TUTO, the advance base of the 1st Engineer Arctic Task Force. In the background is the beginning of the Greenland Ice Cap, July 1956.

that their findings would apply to the construction of airstrips in other ice locations with sufficiently level terrain.

In 1956, Boston University, involved in expanding its campus, bought the building on Commonwealth Avenue in which ACFEL had leased its quarters. In March of that year, ACFEL needed to move. The New England Division of the Corps had arranged for temporary quarters at the Murphy Army Hospital in Waltham, Massachusetts, but had not arranged for a paralyzing blizzard that struck the city the very same day that ACFEL was forced to move. It seemed somehow appropriate that the Arctic Construction and Frost Effects Laboratory, after having endured the rigors of Alaska and Greenland, should suddenly become snowbound while moving several miles from Boston to Waltham. Most of their trucks got stuck in the snow, but the personnel of ACFEL had been told to complete the move within 24 hours, and complete it they did.

Unfortunately, ACFEL's relocation to the Murphy Army Hospital was far from satisfactory. There was a shortage of space, a lack of adequate facilities and "various other operational difficulties." These deficiencies resulted in the curtailment of several important ongoing investigations. But soon ACFEL's research programs were again in force, including studies of pile performance in permafrost, frost penetration in soils, closure phenomena in ice tunnels and development of new ground temperature monitoring equipment for frozen soils. By 1960, ACFEL occupied 29,380 ft^2 of working space in three buildings at the hospital, which by then had been con-

verted primarily into the headquarters of the New England Division of the Corps, and had a staff of 33 employees. Furthermore, the testing laboratory was equipped with more than 250 pieces of testing equipment, and it had three walk-in coldrooms by that time as well.

SIPRE

On 27 August 1947, R.L. Tolbert of the Engineer Research and Development Division, of the Office of the Chief of Engineers, wrote a proposal to Colonel Dean, then commanding the Division. It was entitled, "Snow Mechanics Laboratory."

This was the beginning of SIPRE, the Snow, Ice and Permafrost Research Establishment. This proposal initiated a conference, called by the Engineer Research and Development Division, OCE, and held on 25 September 1947. The purpose of the conference was "to ascertain the feasibility and desirability of establishing a Snow and Ice Mechanics Laboratory, on a Department of National Defense basis, for service to all Branches of the Army, Navy, Air Force and other Government Agencies."

As originally proposed, the funding for the establishment of SIPRE was estimated at $90,000 for fiscal year 1949 and $198,000 for fiscal year 1950 and these costs would be split equally among the three services. On 3 March 1949, SIPRE was given a temporary home at the U.S. Army Map Service's Headquarters in Washington, D.C. Although the official order establishing the lab had yet to be made, the Map Service was given comprehensive background information on the organization, function and administration of SIPRE. One engineer would be designated as Temporary Director of the Establishment and two others as his assistants. Two clerical workers would handle the secretarial and typing chores and the services of three or more consultants would be obtained. On 3 March 1949, General Order No. 2 officially established SIPRE.

SIPRE's move from temporary quarters in Washington—where the Establishment was little more than an organization on paper—to more permanent quarters in the St. Paul District came soon afterward. OCE's implementing memo was explicit about the operation and function of SIPRE; and it authorized the St. Paul District to recruit SIPRE's staff and to contract with private institutions "to analyze the requirements for an orderly program for research in snow, ice and permafrost."

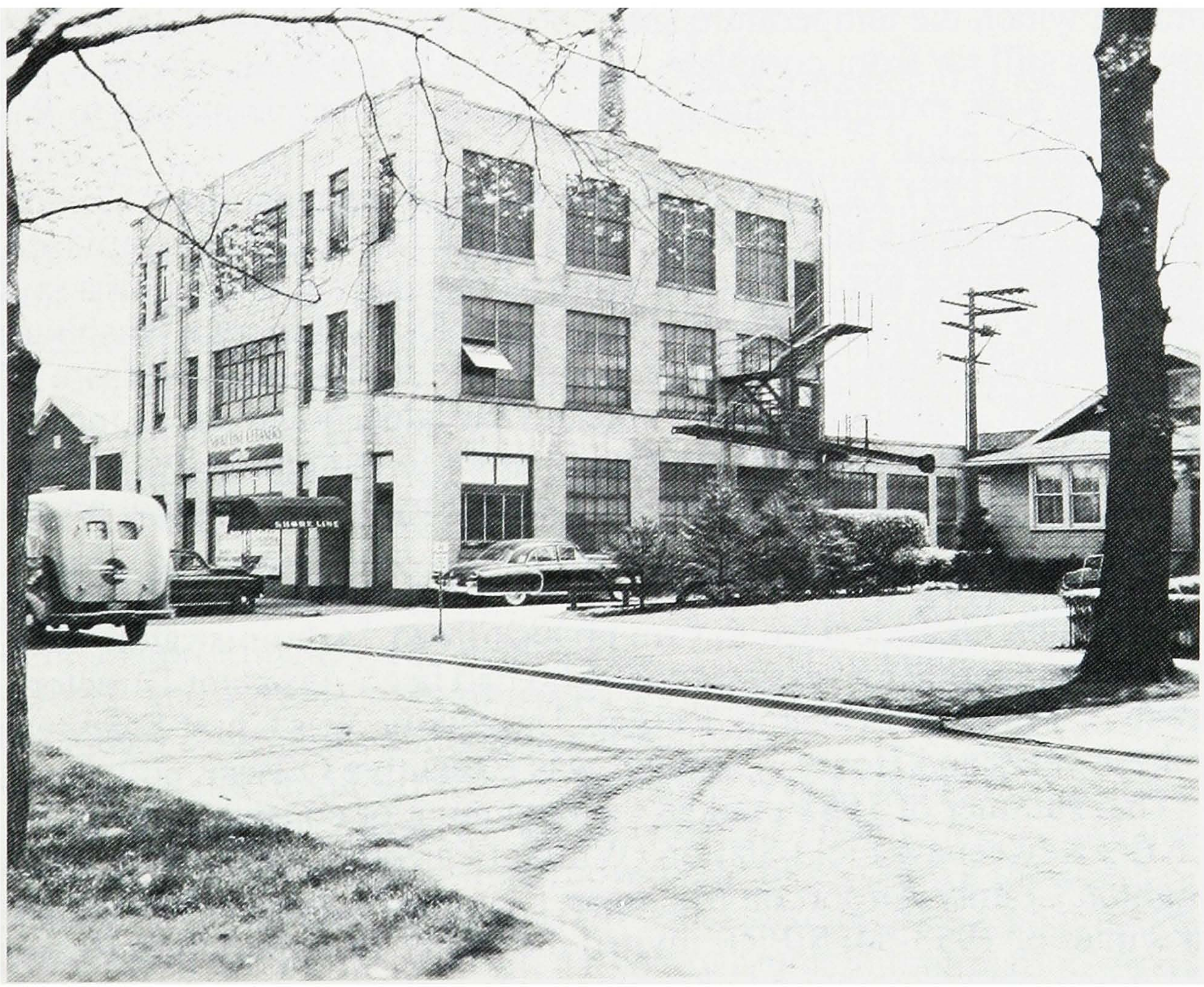
For those first 2 years of its life, SIPRE had no lab it could call its own. Nevertheless, the scientists of SIPRE did make use of the facilities of the Central Sierra Snow Laboratory for the collection of micrometeorological and other data pertinent to snow and ice research. The Central Sierra Snow Laboratory was one of four labs that participated in what was called the Cooperative Snow Investigations, founded in 1945, and under the overall jurisdiction of the South Pacific Division, Corps of Engineers.

This situation was changed by the outbreak of the Korean Conflict in June of 1950. OCE requested that the St. Paul District find a new, more functional home for SIPRE and by 23 October, Henry Manger (SIPRE's Chief) wrote that cities then being considered as possible "permanent" locations for SIPRE included: Boston, Cincinnati, Dayton, Denver, Fair-

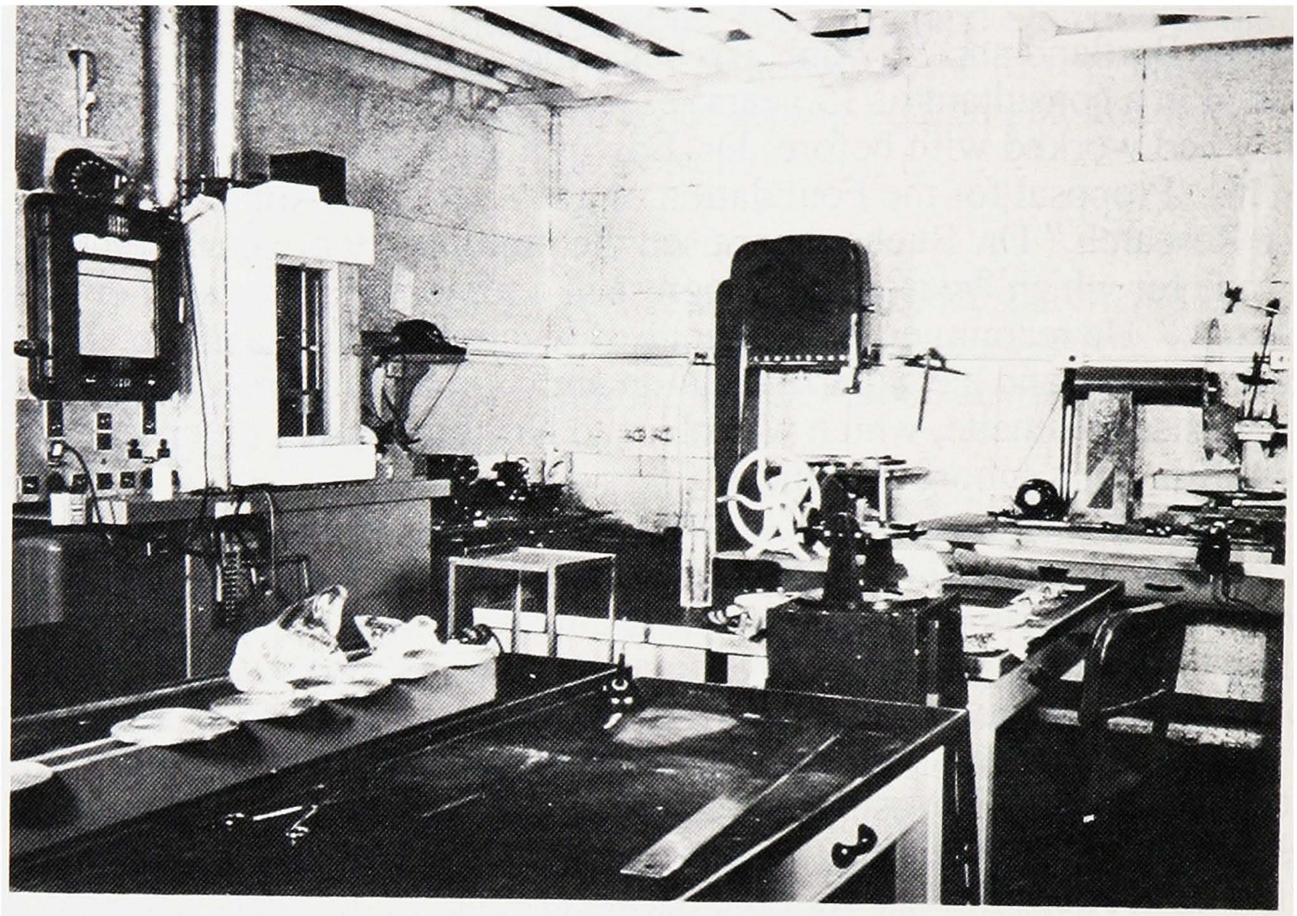
banks, Portland and St. Paul. To help find a suitable location, SIPRE called in a consultant of 15 years' experience in snow and ice research, one they had worked with before: Dr. Edwin E. Bucher of Davos, Switzerland. In his "Proposal for the Foundation of an American Institute for Snow and Ice Research," Dr. Bucher appraised the preliminary organization of SIPRE as one for which "reasonable progress in a reasonable time cannot be expected." He recommended a change of location close to a university equipped for snow and ice experimentation and—separate from the report—suggested Wilmette, which was close to Northwestern University in Evanston, Illinois, a suburb of Chicago.

The new home for SIPRE was a three-story, 10-year-old building with a total floor area of 11,000 ft^2 and a parking lot for 8 cars at 1215 Washington Avenue, Wilmette, Illinois, about a mile north of Northwestern University. Of the nine properties investigated in the area from 9 to 11 April, this building, then housing the "Shore Line Cleaners," seemed to be the best.

The official moving date had been set for 1 July, and what the SIPRE staff found at 1215 Washington Avenue in Wilmette was the remains of a cleaning establishment that had not been cleaned out. Their sign still proclaimed them as the "Shore Line Cleaners" and, until it was removed, they were said to have been approached with the neighborhood's dirty linen.



Building occupied by SIPRE.



SIPRE coldroom.

Although SIPRE finally had its laboratory at Wilmette, with six coldrooms in which the temperature could be controlled to -58°F, its personnel roster was still far from complete. Specialists in the fields of snow, ice and permafrost were extremely hard to find. In all, 17 people moved to Wilmette from St. Paul.

In June of 1951 Lieutenant Colonel Lahlum was appointed Commander of SIPRE. When his tour of duty ended in the fall of 1952, he advised OCE not to replace him with a military commander but to appoint a civilian, instead. As a result, OCE decided to appoint Dr. A. Lincoln Washburn as SIPRE's Director and, under his guidance, the staff soon grew from 17 to 30. When Dr. Washburn's father died a year later, however, "Linc," as he had become known, resigned his post in order to administer his father's estate. But he did maintain ties with the Laboratory as a consultant on glacial geology.

In 1953, James Gillis was appointed Acting Director of SIPRE, and one year later, OCE decided to firm up his title to "Administrator." Dr. Henri Bader, another Swiss scientist who had been Assistant Director of the Bureau of Minerals Research, Rutgers University, was Chief Scientist during these years and Henry J. Manger was Executive Officer.

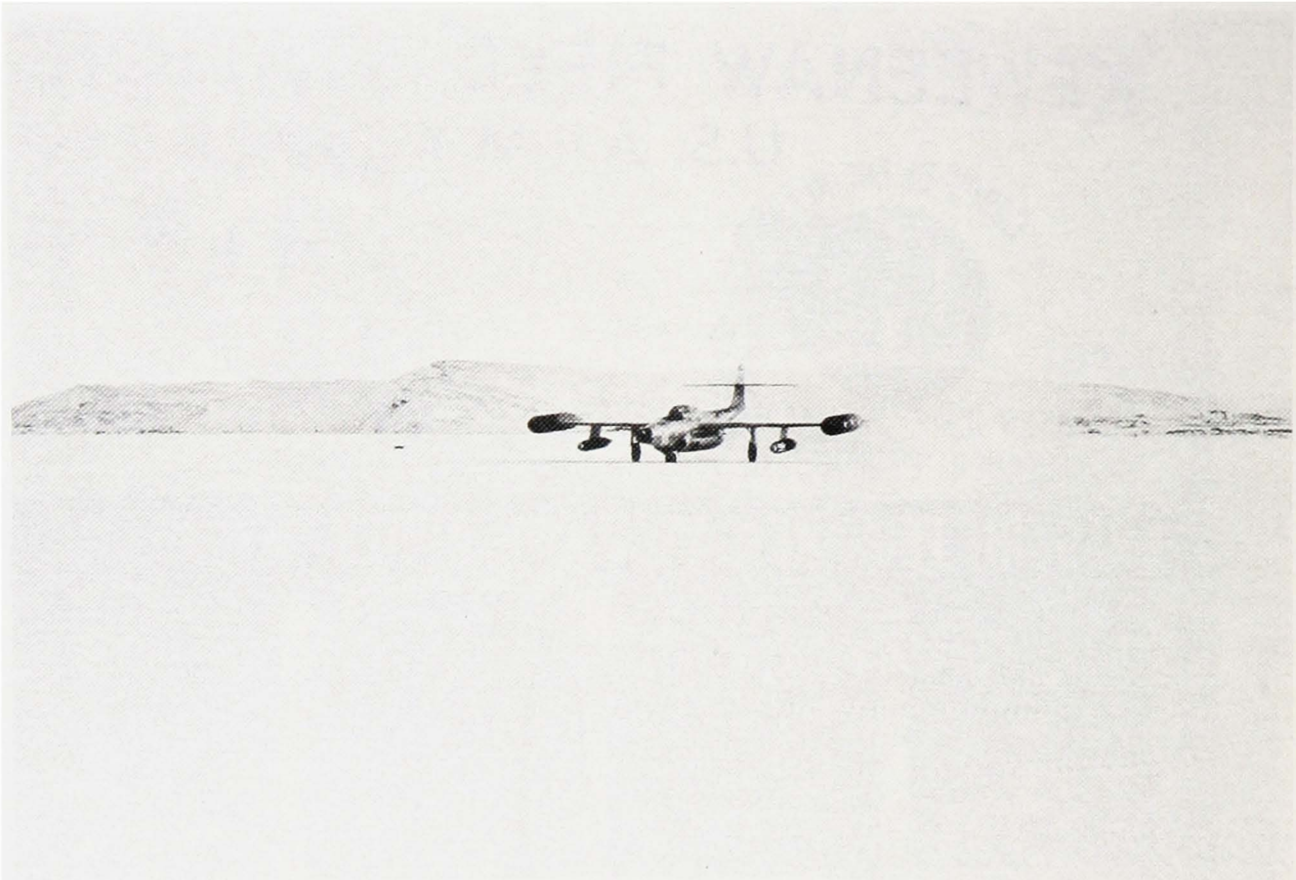
That summer of 1953 marked the beginning of construction on SIPRE's Keweenaw Field Station (William Parrott, Chief), located near the Houghton County Airport on Michigan's Upper Peninsula. During their first winter of 1953-54, SIPRE invited the Army Transportation Research and Engineering Command to Keweenaw to test a number of standard and experimental vehicles in the Michigan snow. In 1956 this organization

Sign at Keweenaw Field Station.

erected approximately 4000 ft^2 of shop space and another 4000 ft^2 of office and utility space for their own use.

Through the years that followed, many government agencies and private industries working on government contracts came to the Keweenaw Field Station. In 1957 the Signal Corps Meteorological Team, from the U.S. Army Electronic Proving Ground, selected Keweenaw as the area to evaluate instrumentation to support the Army research and development programs in the Arctic. This organization, too, enlarged the facility to accommodate its operations during the winter months and maintained a permanent complement of seven. During its tenure as SIPRE's Field Station, Keweenaw served as a test site for elements from the Ordnance Tank Automotive Command, Detroit Arsenal, Land Locomotion Laboratories, Quartermaster Laboratories, General Motors Proving Grounds, Aberdeen Proving Grounds, Waterways Experiment Station and Engineer Research and Development Laboratories. SIPRE's permanent staff of 20 employees maintained approximately 100 vehicles at Keweenaw, including tractors, snow plows, and various sizes of trucks and trailers, not to mention expermental models of vehicles undergoing arctic tests.

Meanwhile, the main SIPRE research staff was also increasing and in 1956 it was decided to convert the entire laundry building into a laboratory. Some administrative functions were moved two blocks down the street into the upper floors of an Odd Fellows Hall, which also housed a pool hall and restaurant. Also, the Purdue University photographic interpretation group, which was to form the nucleus of the Photographic Interpretation Research Division, joined SIPRE and was housed in the basement of the Wilmette



Thule, Greenland; F-89 taxiing down sea ice runway, March 1957.

Post Office. Then, in the summer of 1957, additional quarters were found in Evanston—in a fairly new building only four blocks from Northwestern University. However, this building also housed a laundry, which inevitably prompted jokes about SIPRE "being taken to the cleaners again." At that time the professional staff alone at SIPRE numbered 54 persons.

SIPRE's experiments with snow compaction for runways in Greenland began in the mid-1950's. SIPRE's three International Snow Compaction Conferences, held in December 1950, May 1951 and September 1952, soon secured a world-wide reputation in the field of snow compaction. As a result of these studies, increasingly heavier wheeled aircraft began to land on snow-compacted runways in Greenland, Canada and Alaska.

In 1955 a major problem faced the Department of Defense. At the urging of President Eisenhower, the Joint Chiefs had undertaken the complex task of planning the Distant Early Warning (DEW) Line. This network of 50 radar stations was to be built from Alaska to Greenland (during the first phase) along the northern borders of Canada's Northwest Territories. The primary problem, as was immediately apparent to the Joint Chiefs, was one of supply. It was a crash program, and it was felt that transporting the supplies by ship would cause too long a delay.

As a result, SIPRE scientists were asked if supply planes could land on sea ice. When the answer was affirmative, SIPRE was asked to conduct a test that would support these calculations. This test was carried out on the shore of Amundsen Gulf in northern Canada, with a C-124 cargo plane. Measuring devices were set on the ice to measure the deflection caused by the plane and SIPRE scientists were in constant radio contact with the pilot

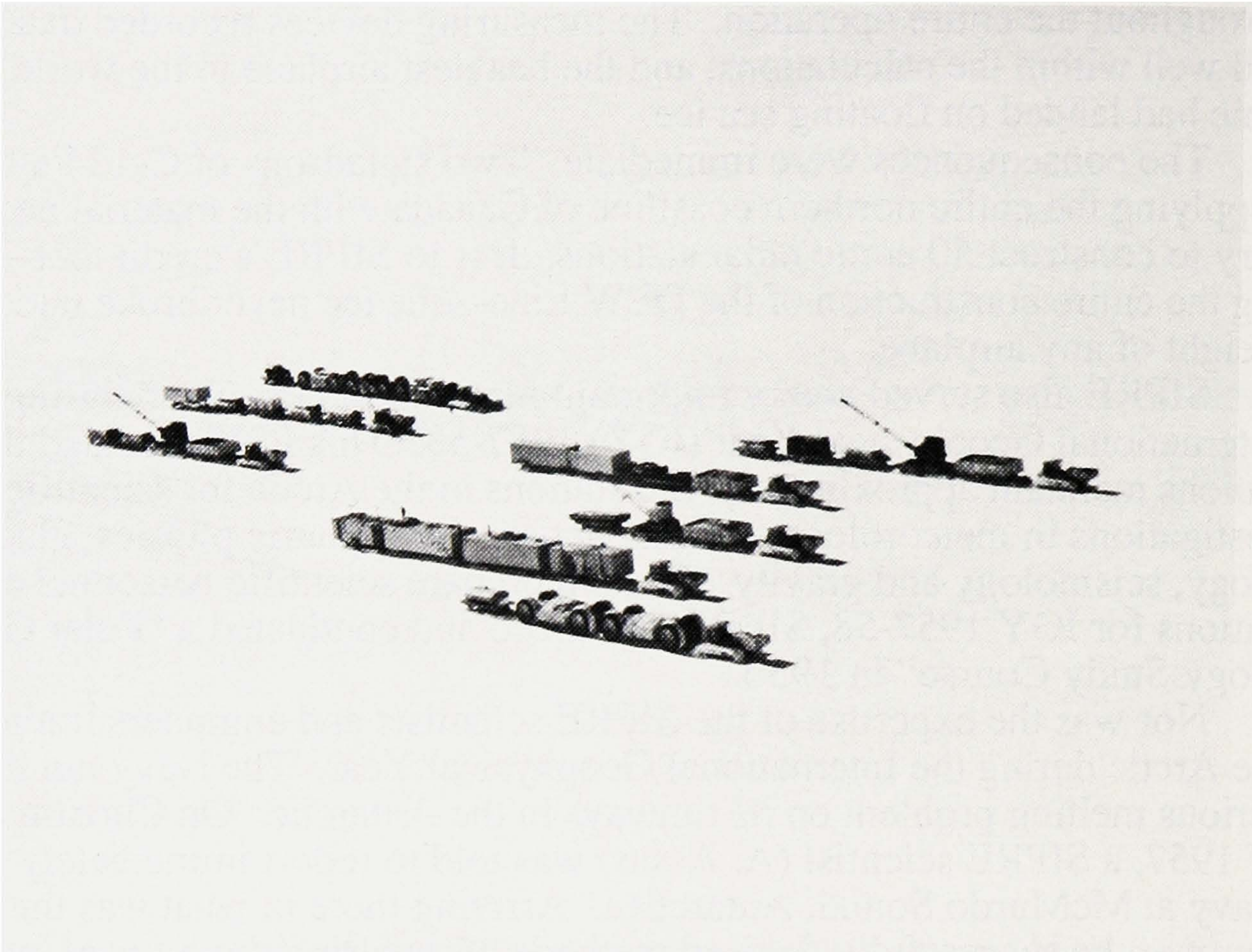
throughout the entire operation. The measuring devices recorded data that fell well within the calculations, and the heaviest airplane in the world at that time had landed on floating sea ice.

The consequences were immediate. Two squadrons of C-124's began supplying the entire northern coastline of Canada with the material necessary to construct 50 arctic radar stations. It is to SIPRE's credit that—during the entire construction of the DEW Line—the ice never broke under the weight of any airplane.

SIPRE also served a very important function in Greenland during the International Geophysical Year (IGY) 1957-58. This IGY provided that 13 nations maintain approximately 150 stations in the Arctic for scientific investigations in meteorology, geomagnetism, ionospheric physics, glaciology, seismology and gravity. To help prepare scientific personnel of all nations for IGY 1957-58, SIPRE organized and conducted a "Polar Glaciology Study Course" in 1956.

Nor was the expertise of the SIPRE scientists and engineers limited to the Arctic during the International Geophysical Year. The Navy ran into a serious melting problem on its runways in the Antarctic. On Christmas Day of 1957, a SIPRE scientist (A. Assur) was told to report immediately to the Navy at McMurdo Sound, Antarctica. Arriving there in what was their midsummer, he successfully devised methods of repairing the runway, which had been entirely unusable because of excessive melting. For doing this, Dr. Assur received the Navy's Distinguished Service Award.

Peter Plow starts to cut ramp for Project 33 at Camp Century, Greenland.

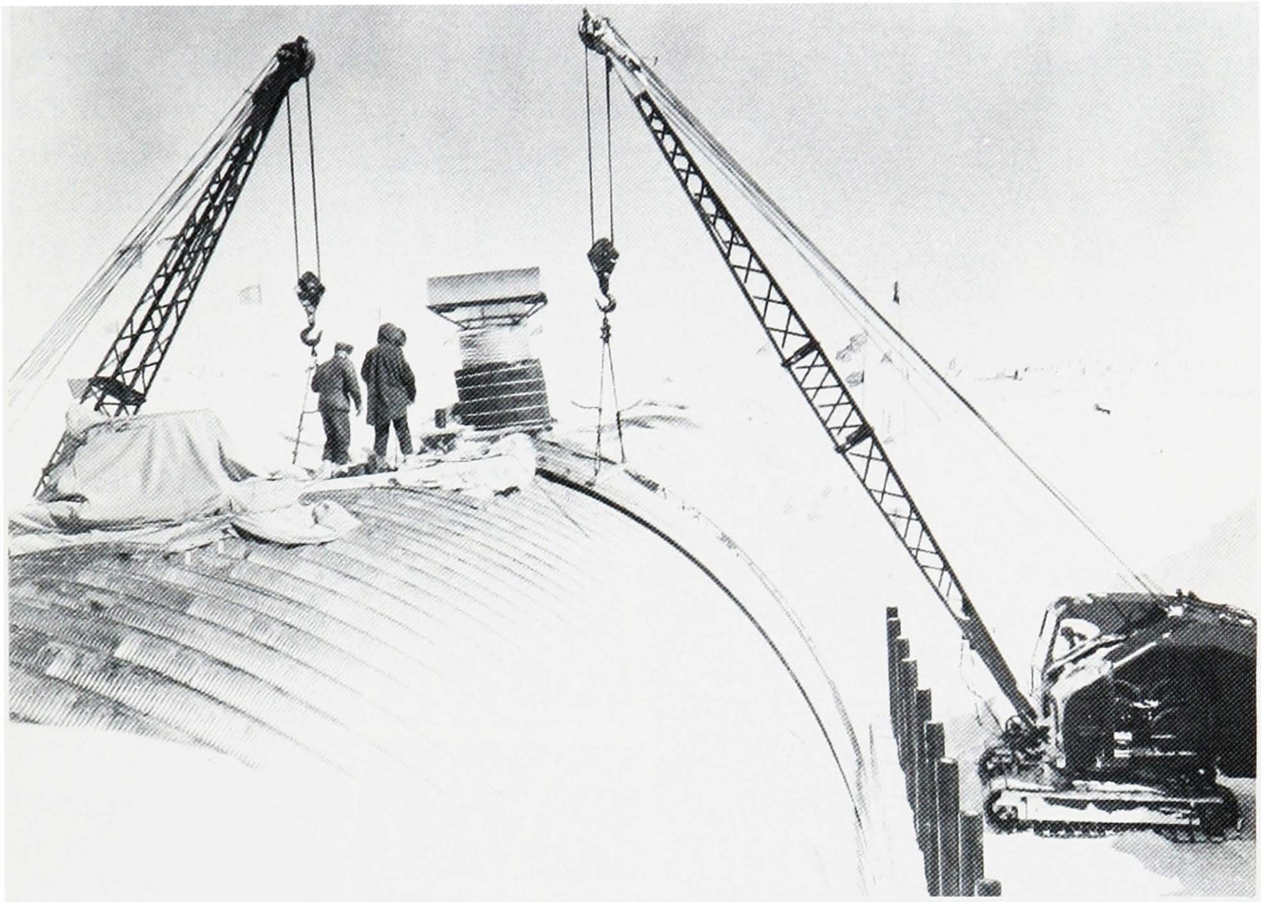


Aerial view of the heavy swing transporting supplies to Camp Century from Camp TUTO.

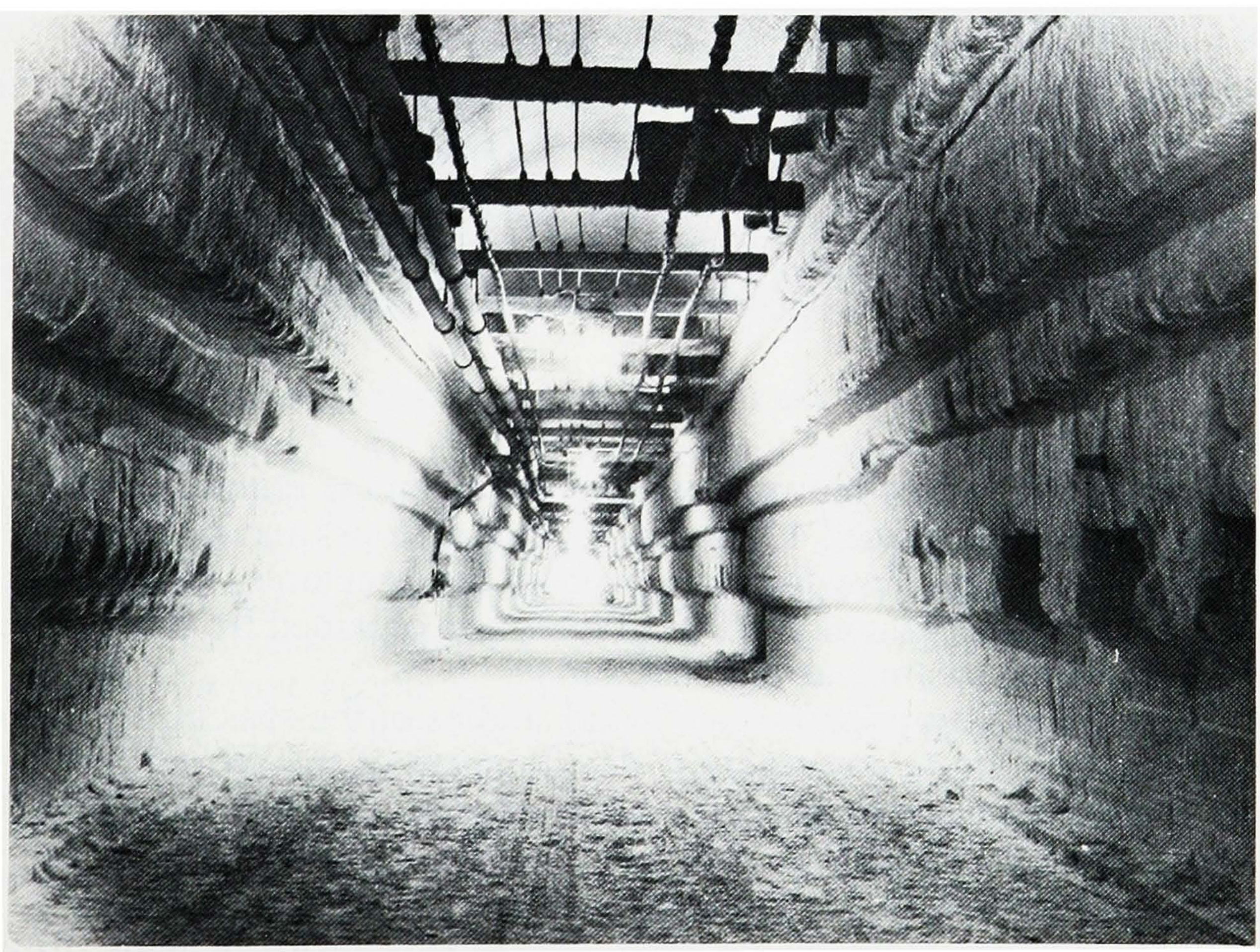
In 1954, SIPRE researchers excavated a pit 100 ft deep in the Greenland snow to determine temperature, density, hardness, strength and permeability of the snow. Two years later, they dug a 30-ft long tunnel, 7-ft wide, at the bottom of the pit. This research led directly to the construction of Camp Century, a city for 100 beneath the snow, located about 140 miles northeast of Thule. Most of the camp's construction was conceived and tested by SIPRE, and this support continued until the experiment was discontinued in 1966.

Named because it was originally located 100 trail-miles out on the ice cap, Camp Century was located in a 6200-ft-high area where winds of up to 125 miles per hour and temperatures as low as -70°F had been recorded. The camp, first occupied in 1959, was officially operated by the Army's Polar Research and Development Center from Ft. Belvoir, but SIPRE played an important part in both its construction and operation.

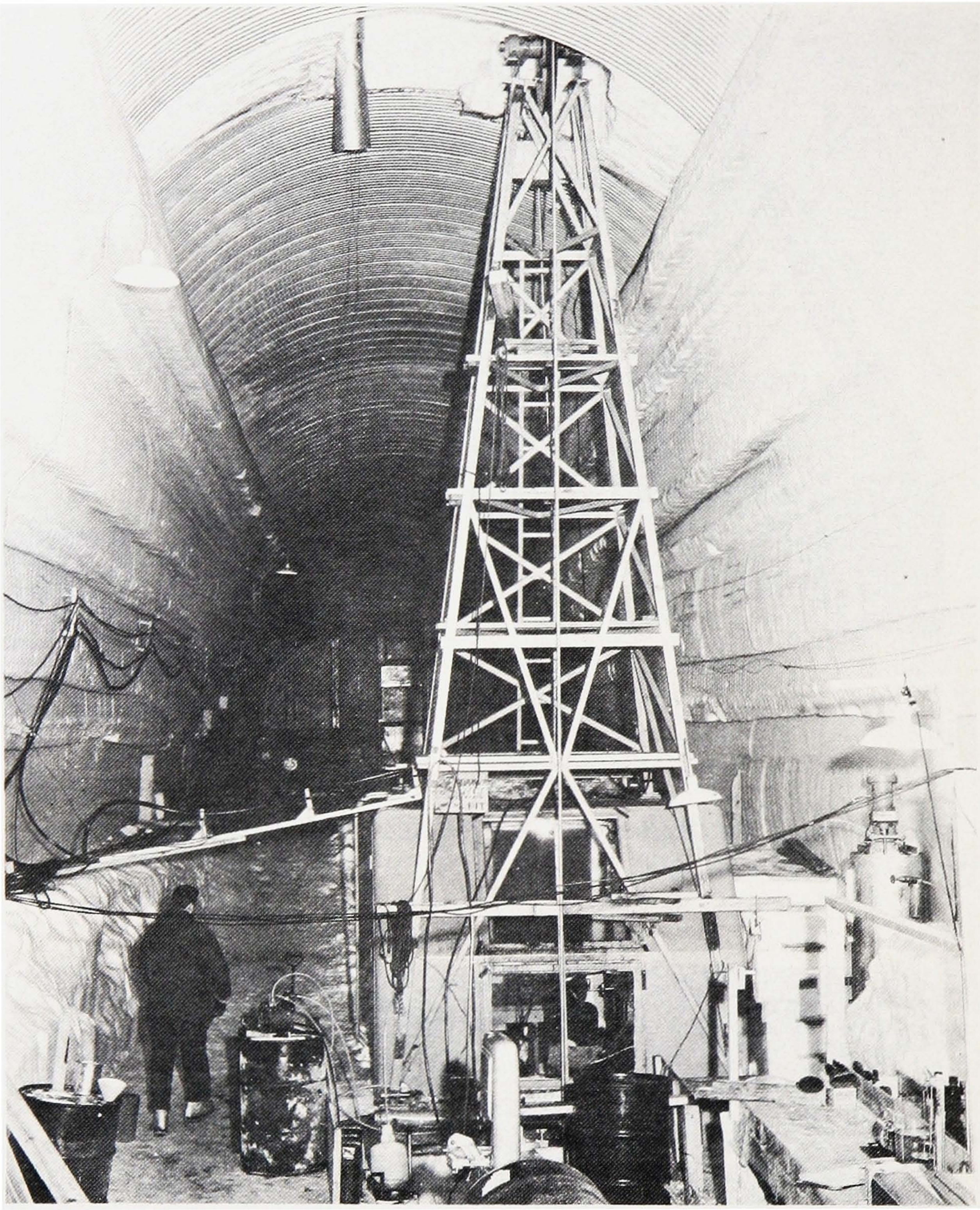
Camp Century was housed in a network of 21 cut-and-cover trenches that were constructed with the Swiss snow millers (Peter plows) and corrugated steel arches. Within the tunnels were placed 30 prefabricated plywood buildings that contained research labs, dormitories, a mess hall, a nuclear reactor for heat and power, a dispensary, a gymnasium, a barbershop and a laundry. The largest of the tunnels, known as "Main Street," was 1100 ft long, 26 ft wide and 28 ft high. To prevent melting of the tunnel walls, a large "air well" was drilled 40 ft below the floor of each



The raising of the arches over the Nuclear Power Trench at Camp Century.



View of main trench at Camp Century.



View of the thermal drill at Camp Century.

tunnel and cool air was drawn upward to maintain the tunnels at about 20°F. The buildings were placed 4 ft above the tunnel floors and 4 ft from the walls to prevent heat flow to the snow from the structures, which maintained indoor temperatures of 70°F. Water was obtained from a well in the snow into which steam was injected.

Research at Camp Century included studies of the structural properties of snow and its use in construction, development of transportation equipment, meteorological studies and ice core studies. It was from a tunnel in Camp Century that a CRREL drill team first reached the bottom of the Greenland Ice Sheet in 1966 at a depth of over 4550 ft.

In order to penetrate the ice sheet, the CRREL research team, drilling from one of the covered trenches at Camp Century, first made two unsuc-

cessful attempts with a thermal drill, which melted the glacial ice. On the third hole they substituted an electromechanical drill at 1755 ft to complete the project. The penetration of Greenland Ice Sheet, which had taken nearly 3 years to complete, was a significant technical accomplishment because of the difficulty of drilling through the shifting and flowing glacial ice cap, and it was a major scientific accomplishment because continuous core, representing more than 120,000 years of climatic history, was available for the first time. Since these cores contained dust particles and air pockets that had been incorporated into the glacial ice as it formed from the falling snow, scientists at CRREL and at other laboratories throughout the world were able to reconstruct the previous climate for a period of time extending far beyond the recent Ice Age.

Another important project begun during this period was the establishment of a series of ice thickness measurement stations throughout the Canadian and Alaskan Arctic. These stations, which obtained the first comprehensive ice thickness and ice formation and breakup information for northern North America, were manned by such personnel as Eskimos, school teachers, homesteaders and lodge keepers. As a result of their weekly measurements, a continuous 17- to 19-year record has been published and is now available for meteorological research.

In 1958, Colonel Walter H. Parsons, Jr., was appointed Director of SIPRE, ending the 6-year period of civilian control. Dr. Henri Bader retained his position as Chief Scientist as did James Gillis as Administrator. However, Gillis soon left SIPRE for another position in Washington, D.C., and Bader transferred to the University of Miami (Florida).

In April of 1960, Colonel William L. Nungesser assumed the command of SIPRE from Colonel Parsons, whose tour of duty had expired. Colonel Nungesser, who held a degree in industrial engineering, had previously been on the faculty of the Engineer School at Fort Belvoir, Virginia. The total professional complement of SIPRE, after 10 years, numbered 88 staff members and a board of five consultants. The time had come for SIPRE to further expand, not on its own, but through the creation of CRREL.

THE MERGER

On 1 February 1961, CRREL was established by redesignation of the Snow, Ice and Permafrost Research Establishment and merger with the Arctic Construction and Frost Effects Laboratory, as directed by U.S. Army General Order No. 3. On this date CRREL was officially created. Colonel William L. Nungesser became CRREL's first Commanding Officer and W. Keith Boyd its first Technical Director.

As early as 1953 OCE had searched the continental United States for suitable government-owned buildings that could be refurbished to satisfy the requirements of a home base for a combined SIPRE and ACFEL. They found only two: a warehouse in Seattle and the Government Center in Denver. Neither met the necessary criteria.

Again, in 1954, both SIPRE and ACFEL analyzed this matter of location—basing their analyses primarily on environmental requirements. Their

report showed that essentially five areas were suitable for relocation. These areas, having at least 100 in. of snowfall and a freezing index of at least 1500 degree days, were New England, Upstate New York, the Upper Peninsula of Michigan, the Denver area, and the region near Bozeman, Montana.

Robert Philippe, Chief of the Special Engineering Branch at OCE, favored pursuing further the possibility of a New England location. He arrived at this decision after eliminating the two other principal contenders, the Denver area and the New York state area. The Denver area was soon to become the site of the Air Force Academy and was already headquarters for the Bureau of Reclamation so that it was already surfeited with government activities. As for upper New York State, he considered it too remote from educational institutions and scientists engaged in related work.

He favored the Boston area, because it "is literally surrounded by educational institutions, Worcester Polytechnic, Holy Cross, Wellesley, Brown, Yale, Northeastern, Tufts, Harvard, M.I.T., Dartmouth and many others; many engaged in cold region problems... Also, there exists a severe-cold-weather station at the peak of Mount Washington, New Hampshire. The highway departments of Maine, New Hampshire, Vermont, Massachusetts and New York are actively engaged in cold-regions engineering. It will be necessary to reestablish an elementary field station, possibly at Berlin, New Hampshire, inasmuch as the immediate conditions (in the Boston area) are not satisfactory for some field tests."

Much of the interest in New Hampshire as a site for the new laboratory came from Dartmouth College at Hanover, New Hampshire. Individuals at Dartmouth had heard of the proposed merger and relocation as early as the Autumn of 1954. Notable among these was Dr. John Masland, Provost of the College. As Provost, Dr. Masland was responsible for the curricula offered by Dartmouth and had wanted to introduce graduate studies leading to a master's degree or doctorate in cold regions research. Dartmouth already housed the collected papers of the arctic explorer, Vilhjalmur Stefansson, and had done some research analyses of snow and ice. Furthermore, Hanover residents felt that a cold regions laboratory—with no pollution and with a well-paid professional staff of 200 or more—would enhance their community.

On 27 December 1954, President John Sloan Dickey of Dartmouth struck up a tentative correspondence with General Sturgis:

> "It has recently come to our attention that the Corps of Engineers might be interested in Hanover, New Hampshire, and the immediate vicinity, as a permanent location for the headquarters of the Snow, Ice and Permafrost Research Establishment. We have explored the question in a very preliminary way with Mr. Robert Philippe and the outcome of this exploration seems to us to warrant further serious consideration of the matter."

General Sturgis' reply on 21 January 1955 was favorable:

> "The Corps of Engineers is very much interested in the establishment of a cold regions research laboratory near Hanover. In every way this appears to be a most suitable location, and I propose to pursue vigorously the idea of the location of such a laboratory there."

But General Sturgis was careful to add:

> "In view of the very preliminary nature of our present plans, I feel that our conversations should not become public information at this time. In due course, members of Congress primarily concerned should be informed, and this I propose to do."

Accordingly, he notified both New Hampshire senators, Styles Bridges and Norris Cotton, on 18 February 1955, two days after Philippe had visited Hanover for a talk with President Dickey. The day following this visit (17 February), the Executive Committee of the Board of Trustees of Dartmouth College voted the granting of "parcels of land not in excess of fifteen acres ... to the Government for CREL ... as the Committee on Buildings and Grounds may specifically approve."

The Chief of Engineers was denied building funds under the Military Construction Authorization (MCA) Program for the two fiscal years (1956 and 1957) following the Corps' receipt of the Hanover site. However, a preliminary design for the building was completed on 9 June 1955. Another, more comprehensive design was directed on 30 April 1956 and completed by 7 September that same year.

The 85th Congress approved this appropriation in Public Law 170 on 28 August 1957; it also authorized the establishment of a Cold Regions Engineering Laboratory under Public Law 241 on 30 August 1957. However, a review of the final plans for the laboratory revealed a deficiency that primarily concerned refrigeration; it affected the architectural design of the plan and would cost an additional $1,291,000 to rectify. This would bring the total estimated cost to $3,787,000. Consequently, OCE did not begin construction but, instead, requested the necessary additional funds from the MCA subcommittee of the House Appropriations Committee.

In April of 1959, the Committee rejected OCE's request stating it "is not convinced as to the accuracy of the cost estimates or the desirability of the location and directs that further study of available facilities be made."

The other suggested locations, having been resurrected, had to be once again thoroughly investigated. Denver and the Denver area were unsuitable for the same reasons as before. But the Naval Supply Depot at Scotia, New York, had possibilities that even Philippe had to admit. He had a complete cost analysis made on conversion of the existing facility at Scotia (a warehouse measuring 200 by 600 ft) and found that a minimal savings might be realized if the Corps chose to locate the lab there. However, these savings would soon be offset by foreseeable repair work that would have to be done on the temporary structure erected in 1946.

Finally, in 1959 Congress authorized CRREL's construction—at the previously designated location in Hanover—and granted the project the ad-

Cornerstone laying ceremonies, dinner at Thayer Hall, Dartmouth College.

ditional funds it needed for fiscal year 1960. It had taken nearly 7 years to accomplish this. On 15 June 1960, the cornerstone laying ceremonies were observed.

The practical and logistical problems of moving over 200 people and their families into a small town of only about 4500 inhabitants were formidable. Consequently, on 3 February 1960, a meeting was called in Hanover to discuss these difficulties and solutions to them. Those attending represented a good cross section of the people involved in the relocation, and included individuals from OCE, SIPRE, ACFEL, Dartmouth and the Hanover Chamber of Commerce.

Although housing was the principal topic of discussion in this conference, other subjects were touched upon, including the availability of jobs in the area for the spouses of CRREL employees, taxes, school systems, food prices, the dearth of supermarkets in Hanover (at that time, there was only one) and even the local bowling alley (it had only 10 lanes).

On 11 February, immediately after his return from the meeting in Hanover, Colonel Nungesser issued a full report to everyone at SIPRE and instructed the Planning Committee to prepare a questionnaire to determine how much rental housing would be required. In the subsequent months, he made trips to address the Hanover Rotary Club, the various Chambers of Commerce in the area and other civic groups on the mission and history of

SIPRE and ACFEL. He also recruited some local Hanover bankers to help dispel the notion—then widespread in Hanover—that the introduction of CRREL would dramatically escalate real estate prices.

The usual panic rumors also circulated: that the location of such a laboratory in Hanover would automatically designate the town as a prime military target; that the lab could accidentally blow up at any time, leveling the town; that the "cold regions" label was just a front for nefarious, super-secret experimentation on atomic wizardry and germ-warfare. Colonel Nungesser had a special slide show and presentation designed to dispel these rumors.

On 25 January 1961, General Order No. 3 officially established CRREL (by then the word "research" had been added to its title). In it, Colonel Nungesser was given command jurisdiction over ACFEL as well as SIPRE and the two were finally merged. One of Colonel Nungesser's first accomplishments was to reorganize the combined laboratories, appointing engineers and scientists from them both to head up the divisions and branches. Henry Manger, SIPRE's Executive Officer, had decided not to make the move to Hanover. Colonel Nungesser immediately notified OCE of the impending vacancy and Washington sent him a list of eligible names. In May of 1961, he chose Rodney F. Poland, Jr., who was Chief of Manpower Management for the Corps of Engineers and had worked with both Hallock and Philippe in their initial management development survey of SIPRE.

On 9 June 1961, General Order No. 22 required that the headquarters of CRREL be transferred to Hanover by 1 July 1961. It added: "Activities of the U.S. Army Cold Regions Research and Engineering Laboratory will be continued at both Wilmette, Illinois, and Waltham, Massachusetts, locations during the transition period until all activities can be transferred to the new headquarters."

Accordingly, Colonel Nungesser appointed a small administrative task force—much like the one that pioneered SIPRE's move from St. Paul to Wilmette 10 years earlier—and sent them on their way by 17 July. Although the task force's mailing address was Hanover, New Hampshire (P.O. Box 282), the best they could find for temporary quarters was an old warehouse across the Connecticut River in Hartford, Vermont. This warehouse, incidentally, served for both offices and lab for well over a year.

During that time, as offices and labs in the new building were completed, people would gradually move in. There was much commuting done between CRREL's unfinished laboratory and Chicago and Boston. Ice cores were stored at the Fulton Mart in Chicago and the coldrooms in Waltham. Until coldroom facilities were completed in the new lab, commuting to and from these locations was routine—and tiresome. But morale was high, because the people of CRREL knew they were finally achieving the recognition they deserved in a laboratory especially suited to cold regions research.

By 1 January 1962, the second floor offices of the new building had been completely occupied and the basement had been completed. The basement housed only refrigeration equipment and a machine shop. Luckily, as it turned out 4 days later, the New England Division had refused

CRREL permission to use the basement as a storage area until the entire building had become operational. The designers had designated the first floor to be used primarily as a laboratory area, with 24 coldrooms at the core. The contractors had scheduled the completion of this section for last. It very nearly was last: the last of the entire building.

On Thursday, 4 January, at 6:30 a.m., a worker engaged in constructing CRREL's coldrooms reported to work as usual. His first job, each morning, was to light fires under several kettles of tar that had been placed at various locations around the area in which the coldrooms were being built. The coldrooms were being built of 1-ft-thick foamed glass blocks and the adhesive used for both blocks and the overlying insulation was tar. The contractors had been heating the tar outside in a large vat and transferring it, as needed, to smaller kettles within the building. However, it was necessary to rig small gas burners under the kettles in order to keep the tar hot. These were fed propane gas through a rubber hose from several tanks in the area.

After lighting the first burner, this employee left to light the others. But when he returned, he found the entire wall behind the pot was ablaze. He tried to extinguish it with a fire extinguisher but a propane tank exploded, spewing flames around the entire room. He then sounded the alarm. Luckily, he escaped with only minor burns. The fire soon spread to envelop oth-

Smoke at CRREL's front entrance during construction fire, 4 January 1962.

er partially completed coldrooms and tar pots. The heat generated by these, combined with the fire from the propane gas, melted foamed glass walls, pipes and even some structural beams.

The Fire Departments of Hanover, Etna and Lebanon all responded to the blaze. Although the fire was never out of control, it was extremely difficult to fight because of the heat and the tremendous volume of acrid, black smoke it caused. The firemen had to wear breathing masks. They soon required additional oxygen, which was flown from Pease Air Force Base in Portsmouth, New Hampshire.

The fire was contained about 10:00 a.m. that morning, but the entire building had been severely damaged by the smoke. Water on the first floor was about 2 in. deep. Estimates of the damage were close to $350,000, but the cost caused by delay was incalculable. No sooner had the staff finally settled into what they supposed to be their permanent quarters than they were uprooted. The search for improvised labs and temporary office space was renewed and, again, Dartmouth College and the local communities gave their complete cooperation to the people of CRREL. It was necessary to replace most of the electrical facilities and wiring in the new building. And scrubbing the building down to rid it of the soot and grime left by the smoke took many months. According to some, it could still be sensed after a full year had passed. Indeed, the fire had so disrupted the completion of the laboratory that the dedication ceremonies were postponed until 21-23 November 1963.

CONSOLIDATION AND PROGRESS

In 1962, the Army was reorganized to reduce the duplication of effort among the services. Accordingly, the various Corps' responsibilities were portioned out to Commands that were created specifically to administer to these responsibilities. The training function, for instance, was given to the Continental Army Command, headquartered at Fort Monroe. And research and development were allotted to the U.S. Army Materiel Command (USAMC). According to AMC General Order No. 5, dated 26 July 1962: 275 Corps of Engineers "installations and activities" located in the U.S., Canada and England were assigned to the AMC. One of these was the still not completely operational facility called the Cold Regions Research and Engineering Laboratory.

Some of the CRREL staff welcomed the lab's transfer to the Army Materiel Command because they thought that this change could broaden their mission and the scope of their research activities. Unfortunately, the only immediate change was in the foyer of the new building. The Corps of Engineers had emblazoned its emblem—the castle—on the floor of the lobby. This emblem was soon covered with a rug.

Actually, very little else was changed. Colonel Nungesser was still the Commander, but served under the AMC. CRREL reported directly to AMC as it had previously to OCE. However, OCE continued to work directly with CRREL on many projects because they had a financial stake in the projects' outcome.

CRREL's organization as of early 1962 can be briefly summarized as follows. Colonel Nungesser was the Director; W. Keith Boyd, the Technical Director; Rodney F. Poland, the Executive Assistant; Albert Taylor the Comptroller; Lillian G. Meier, the Office Services Manager; E. Earle Jewell, Chief of the Logistics and Supply Branch; Harry Page, Chief of the Plant and Equipment Branch; Frederick Kitze, Chief of the Alaska Field Station, and F.C. Gagnon, Chief of the Keweenaw Field Station.

The Research Division was headed by James Bender. The two branches in this Research Division, the Materials Research Branch and Environmental Research Branch were headed by Dr. Paul Camp and Dr. Robert Gerdel. The Experimental Engineering Division, headed by Kenneth Linell, contained the Applied Research Branch with Dr. Andrew Assur, Chief, and the Construction Engineering Branch, Edward F. Lobacz, Chief.

In the Technical Services Division (B. Lyle Hanson, Chief) was the Measurement Systems Research Branch, headed by Leonard Stanley, and the Liaison and Technical Publications Branch, headed by Wesley Floyd. In this branch were Eunice Salisbury, the CRREL Librarian and Lucybelle Bledsoe, supervisor of the publications department.

The fourth division was the Photographic Interpretation Research Division, headed by Robert Frost, who was assisted by James McLerran.

The staff at that time numbered about 170 civilians and 40 enlisted men. Of particular note at this time was the number of U.S. Army enlisted men. They were, in general, college graduates who had acquired engineering background and training and had been assigned to the laboratory through the Army's "Scientific and Engineering Assistants Program" (S&E). For many years to come, these S&E's fulfilled an important function in the overall operation of CRREL and, while doing so, probably saved the government hundreds of thousands of dollars. Serving primarily as technicians, the S&E's made substantial contributions to CRREL's technical programs both in the field as well as in the laboratory throughout the 1960's and well into the 1970's. A number of S&E's produced interim or progress reports, which often became the basis for final research or technical reports. But perhaps the most rewarding payoff of all was in the large number of S&E's who continued to work at CRREL after leaving the Armed Forces. These former army specialists became known at CRREL as "the S&E Generation."

Also in 1962 (19 November), Colonel Nungesser wrote the following letter to the Commanding General, U.S. Army Mobility Command:

> "In view of a change in research emphasis of this laboratory under certain projects, it has become evident that considerations should be given to closing the Keweenaw Field Station, reducing the scope of operation and placing the station on a stand-by basis or transferring the station to another command or Army agency..."

Within a month the Army Mobility Command sent a team of four investigators to Keweenaw and AMC General Order No. 23, dated 18 April 1963,

stated "Effective 1 July 1963, the Keweenaw Field Station, Houghton, Michigan, a facility under the U.S. Army Cold Regions Research and Engineering Laboratory, is organized as a class II activity and placed under the jurisdiction of the Commanding General, U.S. Army Mobility Command."

When looked at in retrospect, the transer of Keweenaw was an inevitable step toward a shift of CRREL's research to Alaska. The investigators from the Mobility Command recommended that the Michigan College of Mining and Technology take over Keweenaw's operation. Under the college's direction the Keweenaw Field Station still functions today as a proving ground for experimental engineering equipment designed for cold regions use.

CRREL's research facilities in Hanover were still incomplete during 1962 and much of 1963, but this did not prevent research activities outside of Hanover. For example, the Photographic Interpretation Research Division (PIRD) conducted a study of aerial sensing of tropical surfaces in Puerto Rico in November of 1962. Field work consisted of obtaining aerial imagery (infrared, radar and photo) of selected flight lines covering typical geology, soils, vegetation and land use.

In Antarctica, CRREL studied temperatures at Byrd Station and, in 1963, developed a method that would substantially reduce the rate of snow tunnel deformation. A new ventilation scheme was devised, involving the use of natural convection of cold air through snow pores by means of a slight pressure reduction in the tunnels.

From January until April of 1963, CRREL participated in a joint American/Canadian project called Bold Survey. It concerned the reconnaissance of sea ice and snow-covered terrain by infrared scanners. CRREL's Photographic Interpretation Research Division obtained conventional aerial photographs and infrared imagery of areas in the Gulf of St. Lawrence, northwest Greenland, islands in the Canadian archipelago north of 75°N and of pack ice all the way to the North Pole. Concurrently, Canadian scientific teams in five locations collected surface data in the Arctic Islands and CRREL personnel on a Canadian icebreaker in the Gulf of St. Lawrence obtained additional correlatable data. This project conducted the first infrared reconnaissance mission at the Pole.

At the request of the State Department, a CRREL researcher made an on-site reconnaissance of the area around the Zoji La Pass in northeastern India. On his trip, he recommended snow removal techniques for the military supply line between Leh and Jammu, where winds sometimes exceeded 100 mph and where avalanches and landslides were frequent.

Also in 1963, the U.S. Coast Guard received help from CRREL in testing their icebreakers on perennial and seasonal sea ice in the Kennedy Channel off the north Greenland coast. The New York District, Corps of Engineers, also called on CRREL for help with problems with a BMEWS (Ballistic Missile Early Warning System) radar facility's foundation at Thule. CRREL also served in a consultant's capacity for the New England Division of the Corps in the efforts to alleviate the ice jams and floods that plagued the town of Colebrook, New Hampshire.

Bridge endangered by ice jam (Lancaster, New Hampshire).

Bell Telephone Laboratories asked for CRREL's help in preventing snow and ice acumulation on open mesh metal panels to be used in a major system of missile defense antennas. The CRREL researchers found that electrical resistance heating was the method that proved effective under the widest variety of conditions. Interestingly, the final field tests were performed at South Georgia in the Falkland Islands because of the urgency of completing the project, when it was still summer in the Northern Hemisphere.

Throughout most of 1963 the dedication of the new building was postponed so many times that Colonel Nungesser began to think a formal dedication would appear anticlimatic. On 6 March 1963, he wrote to Major General Frank H. Britton, Director of Research and Development, Headquarters, AMC:

> "As you are aware, we have been planning a dedication ceremony for our new laboratory building for quite a while now, but each time something happens and the date slides further away. In view of the fact that a large portion of our people will be in Greenland and Alaska during the summer months,... any form of dedication cermony should be delayed now until the fall (October- November). In fact, in view of the circumstances, I now recommend that we consider not having any formal dedication ceremonies. We will, of course, have 'Open House' for the local communities after the building is completed..."

General Britton agreed with Colonel Nungesser's recommendation but pressed him for a definite date so that the plans could be announced. Nungesser then set the dates for CRREL's informal dedication and open house: Thursday, Friday and Saturday 21-23 November 1963.

As General Britton said before he cut the ribbon across the laboratory's doors:

> "This will open the doors to the many friends of CRREL visiting today and throughout the open house period. But more than that—it will signal, symbolically, the opening of the doors to new horizons in scientific and engineering achievements."

The dedication itself was limited to a short ribbon-cutting ceremony on Thursday after a luncheon hosted by President Dickey at Dartmouth's Alumni Hall. The open house continued on Friday morning, but on the afternoon of the 22nd, President Kennedy was assassinated and all activities at CRREL were suspended. Colonel Nungesser wrote to John F. Meck, Treasurer and Vice President of Dartmouth, on 4 December:

> "I don't believe the rain nor the sad happenings of that weekend detracted too much from our program, although we felt it appropriate to cancel the open house for Saturday morning...we had over 1700 people taking advantage of the tours through the building and I am sure an additional 600 to 700 would have participated had we been open Saturday...we plan to again have an open house for the local community around Armed Forces Day in May for those who didn't have the opportunity to attend last Saturday."

Now that it finally had a home, CRREL began playing host to many scientific symposia and meetings such as the meeting of the Glaciology Panel of the Committee on Polar Research, National Academy of Sciences, in April of 1964 and the Conference of Commanders and Directors of Independent Laboratories held the following year. And on 4 to 12 May 1964, the lab held a course in cold regions engineering for 20 Air Force officers. This course proved so successful that it became an annual event for several years. Twenty-eight CRREL staff members served as instructors, giving the Air Force students, through illustrated lectures, demonstrations and discussions, the benefits of more than 20 years' research and investigation by CRREL and its predecessor organizations. CRREL's expertise was thus applied to operations and maintenance at northern air bases and the DEW line.

Colonel William L. Nungesser's tour of duty with CRREL ended in July of 1964. The laboratory's supervisory personnel honored him at a luncheon at the Hanover Inn and later the entire CRREL staff give him a farewell reception. There it was said of him that he "brought with him not only the precision and the investigative instincts and training of the engineer, but also the much needed abilities of an able administrator." Colonel Nungesser later returned to Hanover as Commander of U.S. Army

R.O.T.C. at Dartmouth College and, upon retirement from the Army, he became a Vice President of Hanover's Dartmouth Savings Bank.

Colonel Philip G. Krueger of the Army Materiel Command succeeded Colonel Nungesser at CRREL. Colonel Krueger, a West Point graduate, had been Deputy Commanding Officer of the Army Mobility Command's Engineer Research and Development Laboratories at Fort Belvoir since 1962. At the time of the command transfer, the executive function at CRREL comprised four people: the Commanding Officer (Krueger), the Technical Director (Boyd), the Scientific Advisor (Assur), and the Executive Assistant (Poland).

Colonel Krueger submitted a letter of resignation to OCE in early 1966, surprising many of the CRREL staff. On 18 April 1966, Colonel Dimitri A. Kellogg was placed on temporary duty at the laboratory for orientation, and at Krueger's departure, he returned to Hanover as acting Commanding Officer of CRREL. He was to hold that position until a permanent commander arrived—later that summer.

Colonel Kellogg's primary duties concerned the Army Materials and Research Center (ARMC) at Natick, Massachusetts, so that his tour of duty as Acting Commander at CRREL was, for the most part, in absentia. According to Colonel Kellogg:

> "I had asked to command an Army Lab, expecting to get something like the linear accelerator and reactor lab in the Maryland complex, since I have a Ph.D. in nuclear physics. Instead I was sent to CRREL and AMRA [then called the Army Materials and Research Center or AMRC] ... to solve serious personal interface problems in the top management of CRREL and between AMRA and Watertown Arsenal. For a while I commanded both places simultaneously, commuting back and forth. At CRREL, the problem was a personality and jurisdictional clash between Phil Krueger (CO) and Keith Boyd (Technical Director). There was also some in-fighting between AMC and the Corps of Engineers over control (I was sent by AMC)... I like to think that I was at least partly responsible for getting a Corps of Engineers Officer to relieve me..."

During the 8 months of his tenure at CRREL, Colonel Kellogg secured cooperation and respect from the staff. During these months CRREL received an official commendation from AMC for its "outstanding support of the AMC Cost Reduction Program." The commendation concludes: "The efforts of the U.S. Army Cold Regions Research and Engineering Laboratory contributed significantly to the excellent accomplishments of this program and reflect credibility upon the organization and the U.S. Army Materiel Command."

On 6 February 1967, Lieutenant Colonel John E. Wagner signed General Order No. 2 which designated him as Commander and Director of CRREL. Colonel Wagner was a 1950 graduate of West Point, had fought in Korea, served in Germany, had been Military Assistant to the Director and Project Engineer of USAE Waterways Experiment Station (WES) at Vicksburg, Mississippi, among other duties and accomplishments.

But on 12 June 1968, AMC's General Order No. 45 redesignated the U.S. Army Cold Regions Research and Engineering Laboratory as the U.S. Army Terrestrial Sciences Center (TSC), effective 30 June 1968, to the surprise of many at CRREL.

The Terrestrial Sciences Center was an ambitious undertaking. Actually, during its one-year existence, TSC was an organization on paper within which CRREL was the sole functioning laboratory. Perhaps the only indication of CRREL's expanded role as part of the TSC was the Chief Scientist's assignment for 6 months to South Vietnam to learn about difficulties in tropical areas. His mission was only observational, but after criss-crossing the country and making recommendations, he returned with a combat service medal.

Also in 1968, the same CRREL team that had drilled through the Greenland Ice Cap was the first to penetrate the Antarctic Ice Sheet, after drilling through over 7100 ft of ice. Again, a complete core was obtained, which has revealed a wealth of information about the world's past climate and about Antarctica itself.

In 1967, two CRREL researchers received Army Research and Development Awards. Lyle Hanson, who headed the drill teams in Greenland and Antarctica, was recognized for his deep drilling accomplishments, and Dr. Wilford Weeks was recognized for his research on the formation and physical properties of sea ice.

Ice cores in coldroom at CRREL.

In 1967, oil was discovered north of the Brooks Range in Alaska. Personnel from private oil companies as well as the government came to CRREL for answers to the many questions posed by this discovery. In general, the questions addressed two major problems:

1. How could they get the oil out of the frozen ground, the permafrost or from under the Beaufort Sea?
2. How could they best transport the crude oil to the continental U.S.where it could be refined and put to use?

A prominent program during this time was CRREL's participation in the two test voyages of the icebreaking oil tanker *Manhattan*. Five CRREL researchers journeyed aboard the *Manhattan* for the "Arctic Tanker Project," which was financed mainly by Humble Oil, with some assistance from Atlantic Richfield and British Petroleum. The expedition began in September 1969 with two Canadian icebreakers and one U.S. icebreaker trailing the *Manhattan*. The arrangements were for the icebreakers to carry out search and rescue operations if needed, but the main icebreaking effort was the task of the supertanker. The objective was to have the *Manhattan*, the largest U.S. commercial vessel then in service, ram itself into the thickest ice that could be found.

The *Manhattan* eventually succumbed to the ice of McClure Strait, where ice ridges at that time towered up to 40 ft above the water. The ship could neither budge forward nor backward, and, for the first time, called for assistance from the icebreakers. With the help of the icebreakers, the *Manhattan* was ultimately able to throw its tonnnage fore and aft until, 18 hours later, it broke free. It then backtracked and rerouted its trek through the

U.S.S. Manhattan *in arctic pack ice.*

Prince of Wales Strait. Finally, 22 days and 800 miles out of port, the expedition reached clear water in the Beaufort Sea north of Alaska. The Northwest Passage had been conquered.

In April of 1970, a second voyage was begun with three CRREL scientists on board. They sailed the same route almost to Resolute Bay, and then, having secured the data they needed, returned to port. The major reasons for the second voyage were to determine power requirements (43,000 horsepower had proven to be only marginal) and to obtain additional information needed for model studies.

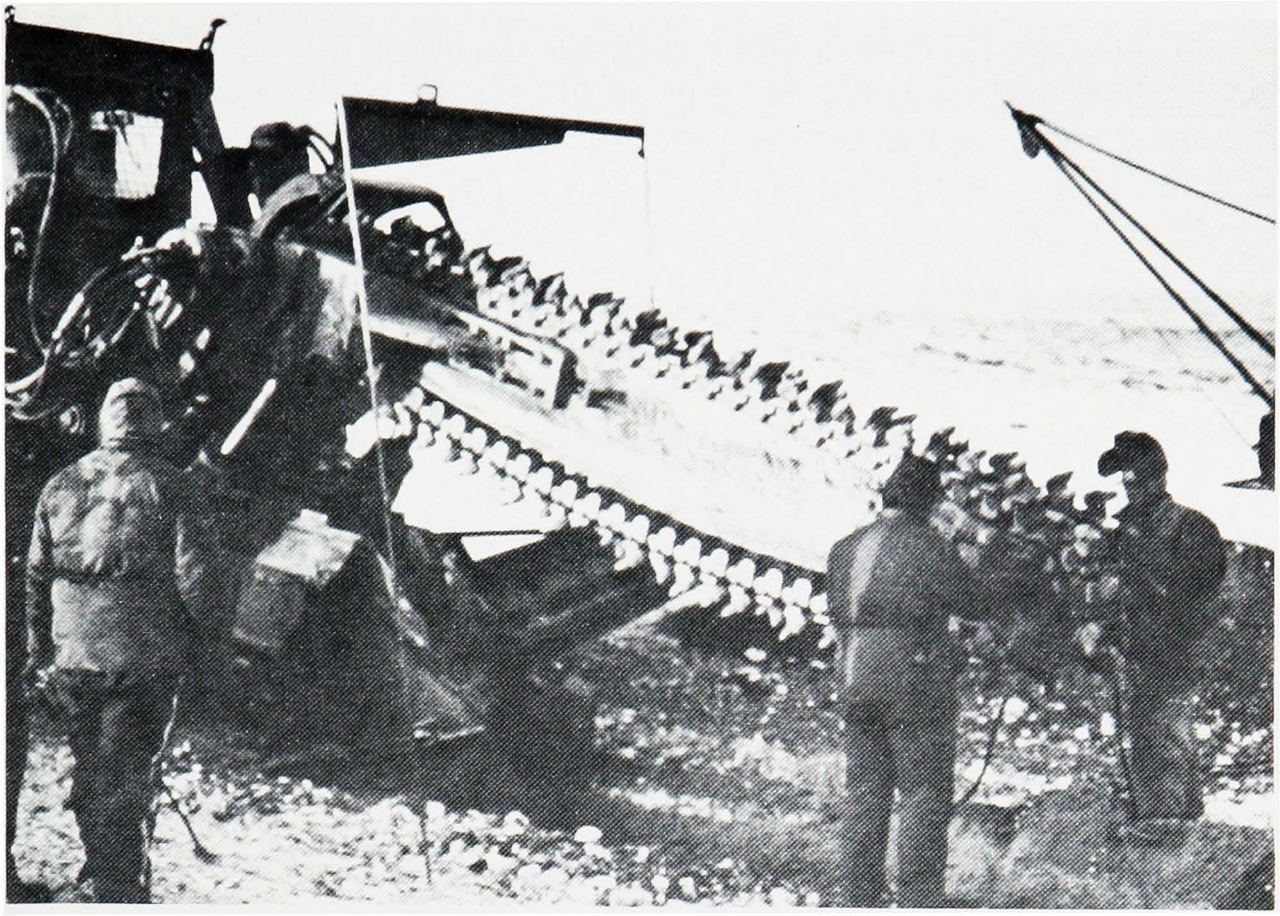
The two voyages had cost in excess of $50,000,000. Nevertheless, Humble abandoned its proposed project of using ice-breaking supertankers to transport oil from Alaska's North Slope to United States markets one year later, as it was about to join the other oil companies that formed the Alyeska pipeline consortium.

Trans-Alaska oil pipeline.

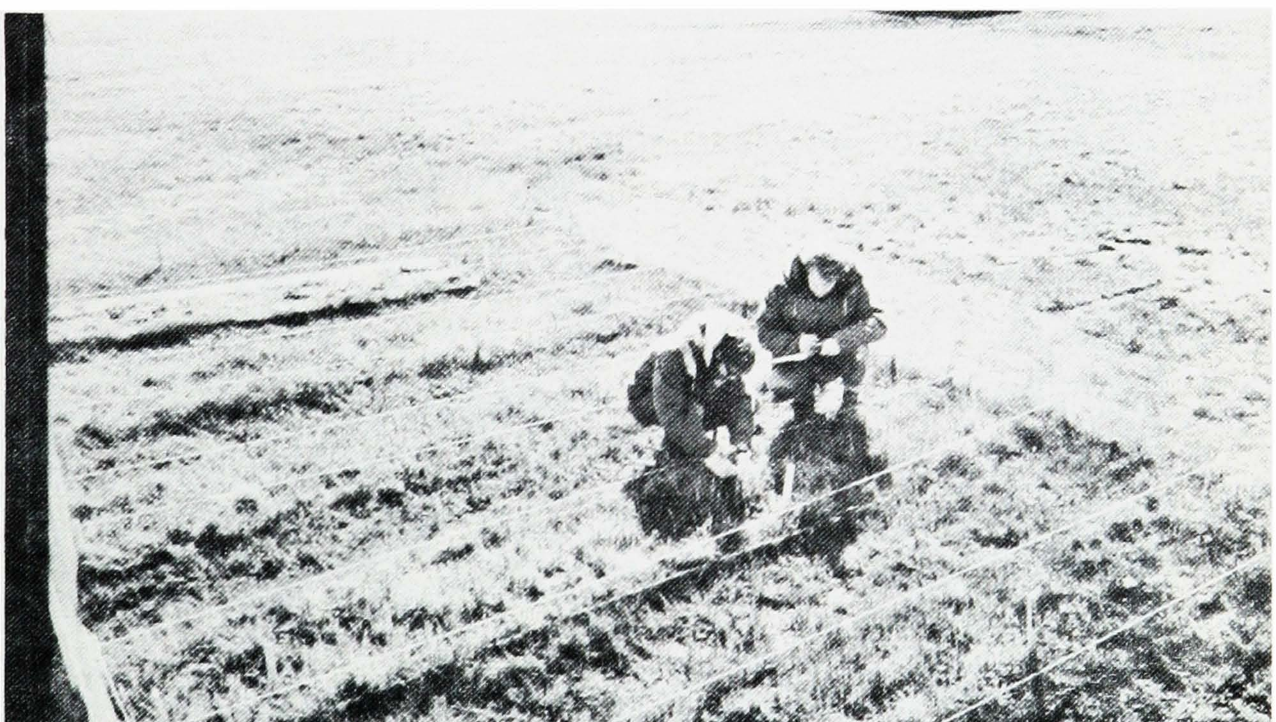
CRREL personnel were closely involved as consultants in the planning and building of the trans-Alaska pipeline. CRREL engineers were on the "Menlo Park Working Group" that reviewed the pipeline design and were consultants to the Federal Inspector for stipulations regarding construction practices. In addition, engineers for Alyeska consulted with CRREL employees and made full use of their knowledge about construction on permafrost. In particular, advice was given on the behavior of piles in permafrost as a substantial portion of the pipeline is elevated on piles to prevent the warm oil from thawing the permafrost below.

During pipeline construction, 35 CRREL employees helped solve problems as they arose and instrumented sections of the pipeline and adjoining haul road for long-term studies that continue today. Recently, CRREL engineers have also been involved with the planning of a chilled natural gas pipeline that will eventually be built near the present oil pipeline.

Augering holes for installation of thermocouples, trans-Alaska pipeline haul road.



Trenching equipment, trans-Alaska pipeline.



Monitoring growth of vegetation in northern Alaska.

At this time there was much concern about the effects of petroleum exploration in the Far North. One of the results of this concern was the scientific study of the region under the U.S. Tundra Biome Program,* directed by Dr. Jerry Brown of CRREL. This program, which began in 1969, culminated in the publication of many books and articles that gave the first detailed descriptions of the environment of northern Alaska.

Ice lead separating floating ice camps in Arctic Ocean.

*A biome is a major ecological zone or region corresponding to a climatic zone or region.

At about the same time of the *Manhattan* voyages, a long-term program called AIDJEX (Arctic Ice Dynamics Joint Experiment) was being initiated, in which several CRREL researchers participated. AIDJEX was a voluntary collaboration of research groups from throughout the United States and Canada who were working on arctic problems. However, despite its unofficial status, the AIDJEX program had a definite plan which centered around deployment of an array of drift stations that would travel through the Arctic Ocean with the moving ice. Most of these stations had automatic signaling systems, but some were manned for periods of several weeks.

On 21 January 1968, a B-52 bomber carrying nuclear weapons crashed on the sea ice about 8 miles west of Thule Air Base, and CRREL was called upon to help in recovering the wreckage. An on-board fire had caused the B-52 to crash into a region of continuous sea ice, leaving a 500 by 200 ft blackened area that was strewn with rubble. Six of the seven crew members had managed to parachute to safety, but one of the crew was lost in the crash.

In charge of the CRREL on-site research was Guenther Frankenstein, who calculated the weight of equipment that the sea ice could safely hold during the round-the-clock recovery effort. At this time of year, the region was in almost continuous darkness (except for a brief period of twilight) and the temperatures were generally below -20°F; nonetheless, the recovery effort was completely successful, with the H-bombs and other important parts of the airplane safely retrieved. In addition, it should be mentioned that several other CRREL employees helped to make this mission successful.

For his work during the B-52 recovery and for his participation in the *Manhatten* voyages, Frankenstein received one of the Army's Research and Development Awards for fiscal year 1969.

CRREL IN THE 1970'S AND 1980'S

It was during the 1970's that CRREL was truly recognized for its scientific and engineering accomplishments. Both individual researchers and the laboratory as a whole received national awards during this decade, reflecting accomplishments that often depended on research done in previous years.

1970-75

Yet it cannot be said that the decade of the 1970's began auspiciously for CRREL. In the nation as a whole, the controversy over the Vietnam War began to assume major proportions in the late 1960's and early 1970's and CRREL was not immune from this. Despite the lab's lack of involvement in the war, a number of students from Dartmouth College, and several other individuals, including the Dartmouth chaplain, marched to CRREL in an anti-war protest in February 1970. Colonel Wagner answered many of the students' questions in an interview published in *The Dartmouth*. He met with Dartmouth's president, Dr. John Kemeny, who agreed to bring to the

students' attention CRREL's environmental programs and its contributions to the local area, as in developing new frost heave criteria for local roads and in preventing ice jams on local rivers.

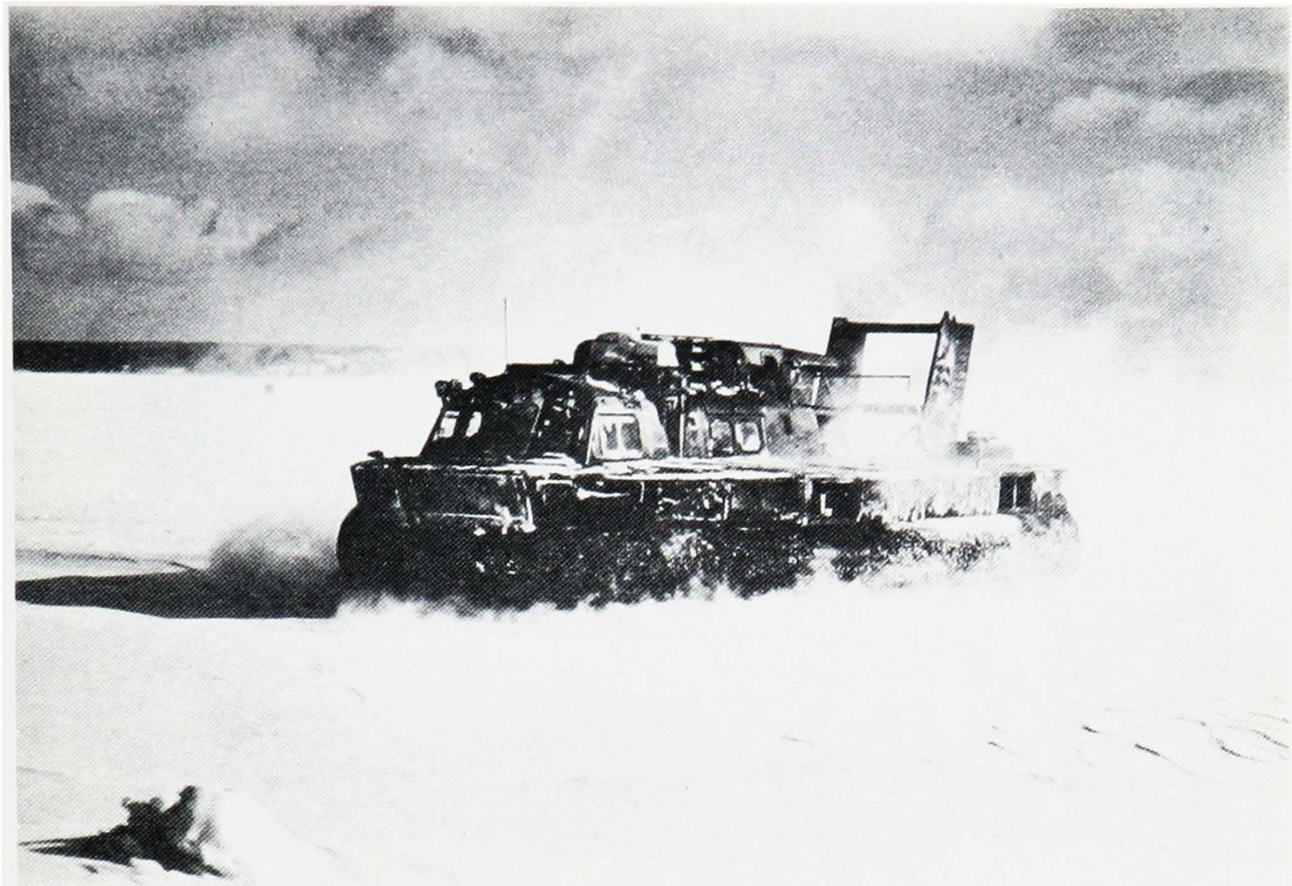
Nevertheless, the protests continued, culminating in sitdowns at the entrance to CRREL's parking lots on 11 and 12 May 1972, during which 31 individuals were arrested. During this and other protests, many of the CRREL employees left their offices to talk to protesters, and on 19 May about 30 war protesters and 60 CRREL employees had a picnic on the lawn in front of the main CRREL building. There were no further protests at CRREL after this informal get-together.

Interestingly, during this period of controversy, CRREL was put under the leadership of a veteran of the Vietnam war. Wagner was succeeded by Colonel Joseph F. Castro, as CRREL's Commander and Director. Castro had previously been a staff officer in the Office of the Chief, Research and Development, and a Commanding Officer of two different combat battalions in Vietnam. His experience with cold regions studies was by way of his assignments as Resident Engineer, DYE-4, Kullusuk, Greenland, and Assistant Area Engineer, Cape Dyer, Baffin Island, Canada.

Castro's tour of duty lasted 3 years, during which a number of significant research programs came to CRREL. Among these was the Advanced Research Projects Agency's Arctic Surface Effect Vehicle (SEV) Program. This study, which was carried out in concert with the National Science Foundation's Arctic Ice Deformation Joint Experiment, investigated the use of these "air cushion" vehicles in the various regions of Alaska. Included in the study were investigations of the size and number of ice ridges in the Arctic Ocean over which an SEV would need to pass, the characteristics of the tundra on Alaska's North Slope and the effect of SEV operations on the tundra itself. Dr. Kay F. Sterrett, who had succeeded James Bender as Chief of the Research Division, was Program Manager of the SEV Program throughout its 5-year duration, and various aspects of the study involved over 30 members of the CRREL staff.

Soon after Castro took command, the Photographic Interpretation Research Division was transferred to the U.S. Army Topographic Command, thus completing the reorganization of CRREL within the Corps of Engineers that had begun the previous year. This transfer involved the loss of 5 S&E's and 20 civilian researchers and support personnel, a significant fraction of the research staff. However, CRREL soon was to gain many more staff members than were lost in the move.

In 1970, two CRREL employees, Robert Northam and Ray May received the Army Meritorious Civilian Service Award for their lifesaving effort during an explosion of trichloroethylene vapor that occurred on 2 July 1970. They were noted for their "display of unusual courage and competence in the rescue of a fellow employee" in their award citation. On 2 July 1970, a CRREL employee, Arnold Goerke, was making repairs with a welding torch while standing on top of a 10,000-gal. tank containing trichloroethylene, when a sudden explosion blew Goerke off the tank, shattering most of the windows in the back of the main CRREL building. The



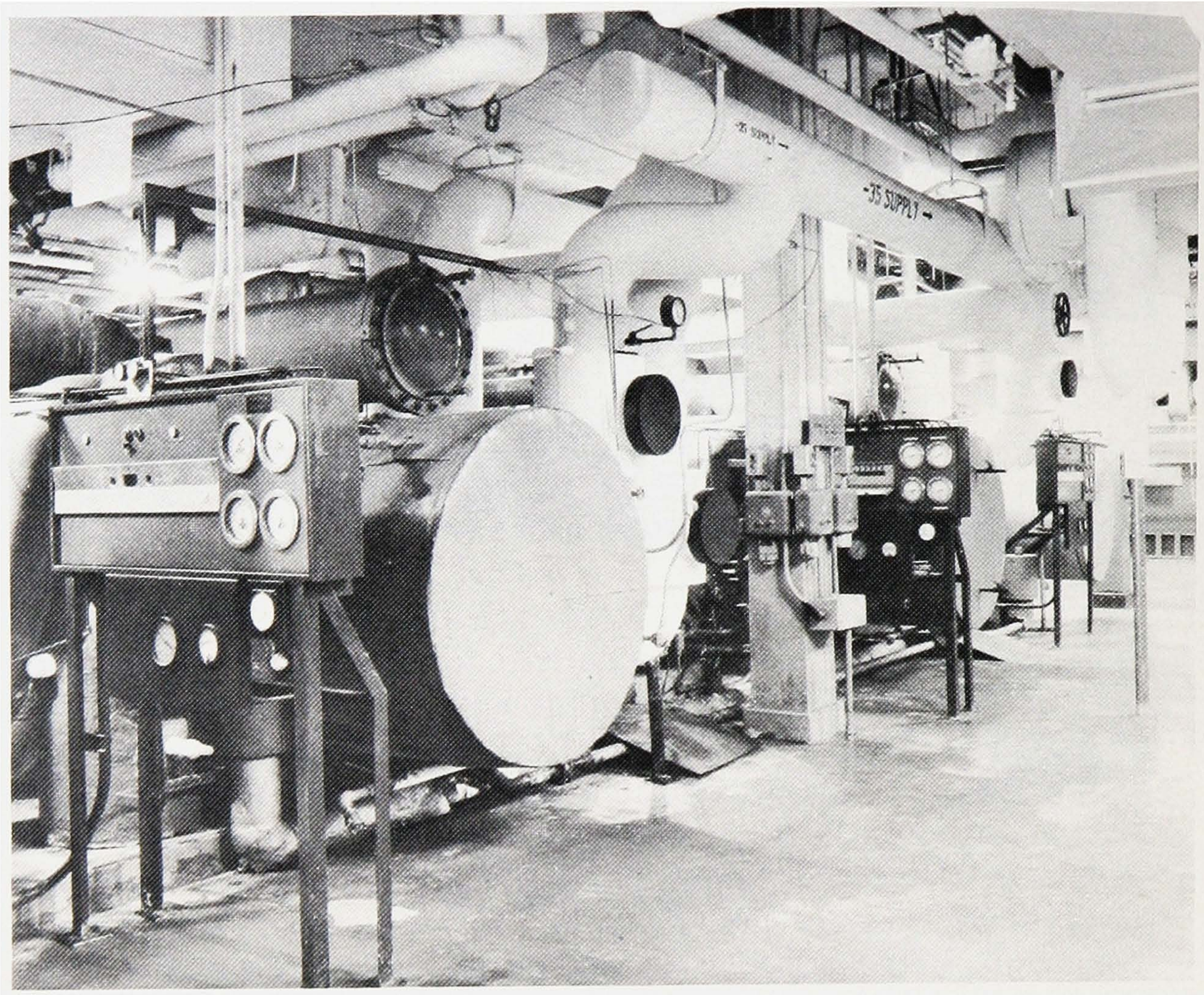
Surface Effect Vehicle.

quick action of Northam and May in rescuing Goerke prevented more serious or fatal injuries.

Trichloroethylene (TCE) is the refrigerant that was used in CRREL's 24 coldroom laboratories (rather than Freon or ammonia as in other systems). Prior to the explosion, TCE was generally not considered to be explosive or even flammable, and this was the major reason for the lack of precaution while welding. TCE was known to be an anesthetic that could be fatal if inhaled in a sufficient quantity for a long enough time. This was why Goerke needed to be rescued quickly. After a brief stay in the hospital, he recovered completely.

The early 1970's also were the beginnings of a long-term program headed by the Corps of Engineers to investigate ways of extending navigation on the Great Lakes–St. Lawrence Seaway throughout the winter. As part of this Great Lakes–St. Lawrence Seaway Winter Navigation Demonstration Program, begun in 1971, CRREL researchers investigated ice booms to impede the flow of ice into navigation channels, and later developed various methods of keeping locks ice-free, including the use of chemical coatings, saws for cutting ice from lock walls and bubblers for preventing ice formation.

CRREL researchers were also deeply involved in maintaining air transportation during the time. James Hicks, a CRREL meteorologist, developed a number of methods of dispersing fog in cold regions in the 1960's and early 1970's. For this work he received a Department of the Army Research and Development Award for 1971. One technique that proved to be particularly successful was the dispersal of supercooled fog with compressed propane gas. Other fog dispersal methods involved the use of heli-



Refrigeration equipment at laboratory.

copters to induce air circulation and of compressed air to cause fog nucleation and dissipation.

An important administrative development during this period was the reestablishment of the Technical Director position at CRREL. On 15 August 1972, Dr. Dean Freitag was appointed Technical Director of CRREL, a position that he was to hold for nearly a decade. Freitag was formerly the Assistant Technical Director at the Waterways Experiment Station (in Vicksburg, Mississippi), another Corps of Engineers research laboratory.

The beginning of a continuing scientific exchange between CRREL and Soviet cold regions research institutions began in 1972 with a visit from two polar researchers from the Arctic and Antarctic Research Institute in Leningrad. The following year, a delegation headed by the Director of the U.S.S.R.'s Permafrost Research Institute visited CRREL. These visits by the Soviet scientists were followed up by a number of visits to the U.S.S.R. by CRREL engineers and scientists.

On 9 May 1973, it was announced that Colonel Robert L. Crosby would become CRREL's Commander and Director, succeeding Colonel Castro who took a position at the U.S. Army Engineer School at Fort Belvoir, Virginia. Crosby had been Secretary at the Engineer School prior to coming to CRREL. A West Point graduate, Crosby had also earned a civil engineering degree from Iowa State University. Taking command on 1 August 1973, Crosby stayed at CRREL for more than 5 years, during

R to L: F.E. Are, Assistant Director of Permafrost Institute, U.S.S.R.; D. Freitag, G. Swinzow, J. Brown, CRREL; and P.I. Melnikov, Director of Permafrost Institute.

which the laboratory expanded greatly both in size and in national importance.

Also in May of 1973, Rodney Poland, Executive Assistant, announced that funds were being sought for a logistics storage building to replace the warehouse that CRREL rented in nearby Lebanon, New Hampshire. Construction of this structure, later called the Logistics and Supply Building, was begun in the fall of 1974, and the $600,000 facility was completed in 1975.

This new facility allowed the Logistics and Supply Office (Raymond May, Chief) to store all of CRREL's sophisticated devices for field exploration and other related equipment at the laboratory. It also greatly aided the shipping and receiving function, as well as providing much needed space for CRREL's purchasing agents.

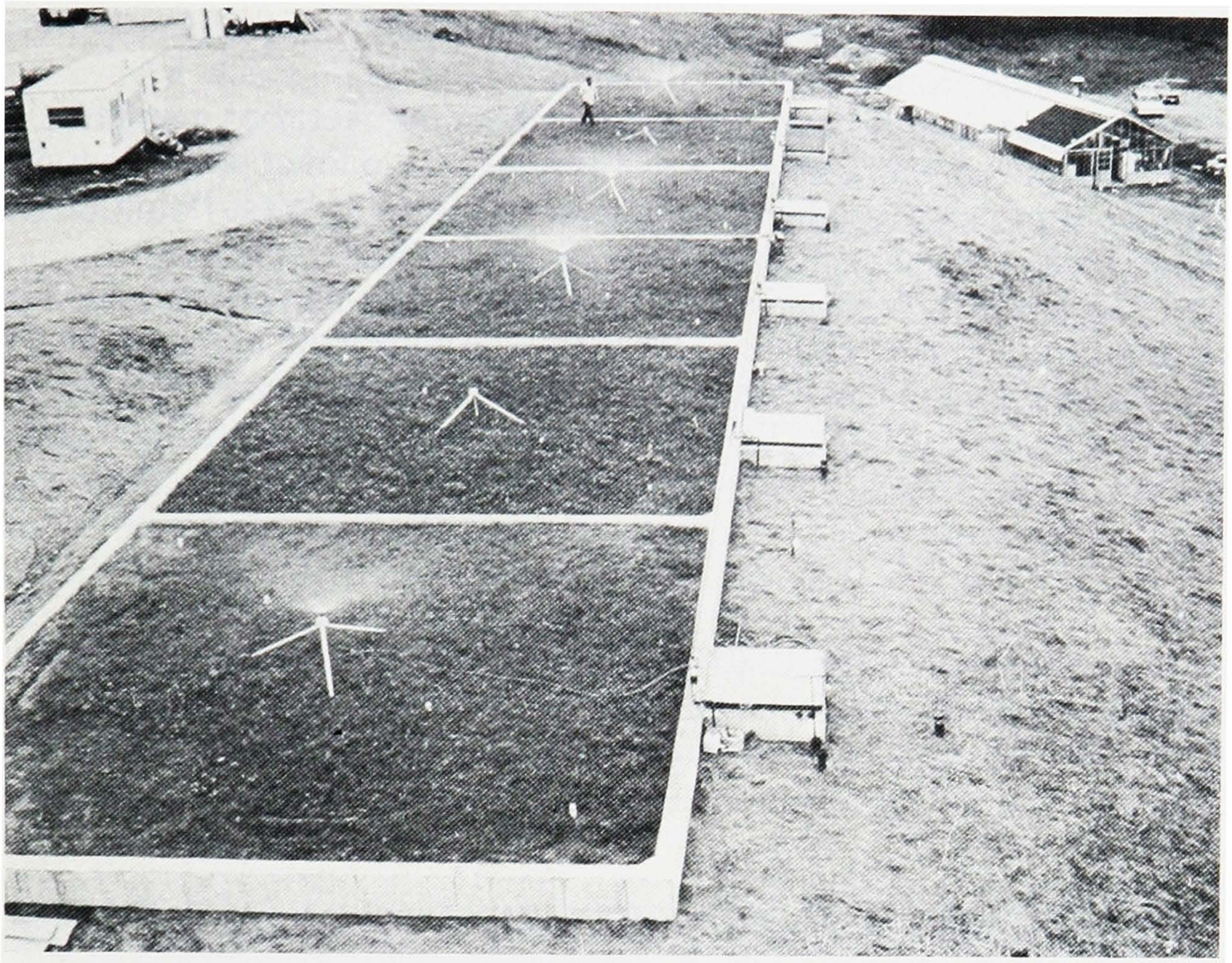
A major research program that began in the early 1970's involved the use of ERTS-A satellite imagery for mapping permafrost distribution in interior Alaska and ocean current patterns in Cook Inlet, near Anchorage, Alaska. This project was primarily directed by Dr. Duwayne Anderson, who was also involved in a program concerned with developing sensors for the detection of moisture on other planets in the solar system. These sensors were carried aboard theViking mission to Mars, and determined the amount of water present on the Martian surface.

In 1974, a major Corps of Engineers program, the Land Treatment Research and Development Program, was begun with CRREL designated as the lead laboratory. Throughout the 6 years of the program, CRREL

Cook Inlet.

researchers made major contributions to the technology of treating wastewater by scientifically controlled application to the land, which was shown to both decrease the cost of constructing land treatment systems and to improve their effectiveness. In fact, cost savings were demonstrated to far exceed the $8 million cost of the program. The Land Treatment Research and Development Program had three program managers during the 5-year period, Sherwood Reed, Dr. Harlan McKim and Dr. Kay Sterrett.

Another project of a much smaller but significant influence was CRREL's pioneering work in detecting heat loss through building walls and roofs with infrared imagery. An early application was a survey of selected building walls at Dartmouth College, during which especially significant heat loss was detected in certain areas of some of the buildings. One inexpensive corrective measure that was taken was the installation of metal re-



CRREL land treatment facilities in Hanover.

Infrared roof moisture monitoring equipment.

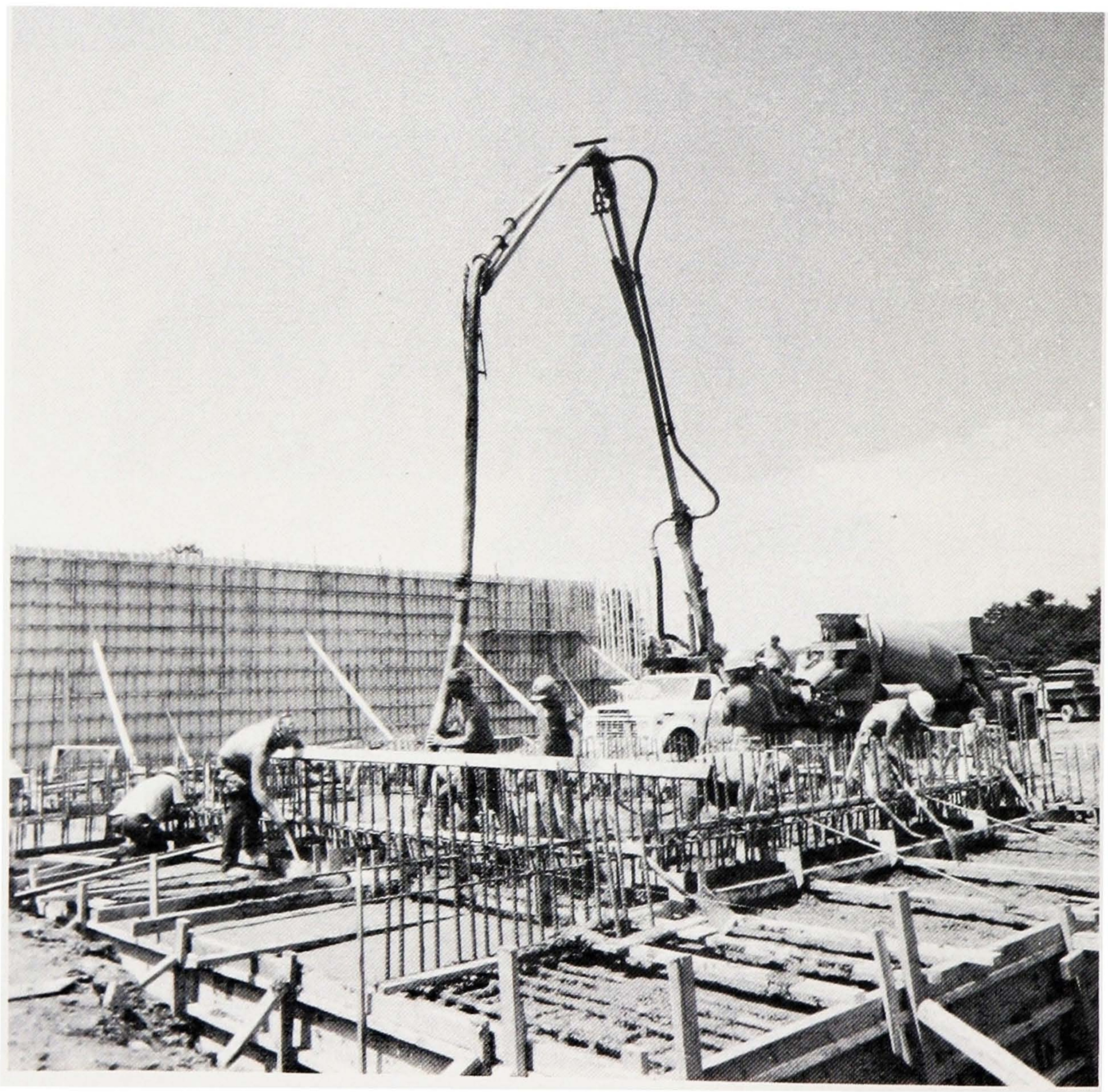
flective panels behind the radiators in several buildings, significantly reducing heat losses from these buildings.

In addition, a method was devised for detecting wet roof insulation with the infrared scanner, since the wet insulation would conduct heat more readily. Roof moisture studies have been conducted at West Point, Pease Air Force Base, Fort Devens and Rock Island Arsenal.

In 1974, CRREL received its first Award for Excellence from the Research and Development Office of the Army. This award was presented to Colonel Crosby by the Chief of the U.S. Army Research and Development Office in July of 1975. This award was one of the first official acts of recognition by the Army of the overall excellence of CRREL's research program.

1975-80

The second half of the 1970's showed a further increase in the growth of CRREL—in staff, physical size and research budget. In fiscal year 1975, the CRREL staff numbered 240 and in 1980 this had risen to 263; CRREL's total building space in 1975 was 122,000 ft^2 and in 1980 it was



Ice Engineering Facility—concrete pouring.

nearly 240,000 ft^2; in 1975 the laboratory's funding was about $7 million and in 1980 it was well over $14 million.

Two major construction projects took place during this time. The first was the construction of an addition to the main building during 1976-77. The 24,000-ft^2 addition increased the main building's size by about 50% and greatly expanded CRREL's research capabilities. In the addition were several specialized laboratory rooms, including those for the study of electromagnetics, acoustics, optics, ice adhesion, heat transfer, microbiology, water and ice chemistry, sanitary engineering, thermophysics and materials testing. In addition, the soils laboratory was doubled in size, a large room with controllable humidity was added, and office space was increased significantly. New executive offices were also provided in the addition, which is now home for CRREL's Plans and Programs Office (Alan Wilson, Chief), responsible for the lab's research planning and analysis.

The addition also eventually brought about expanded space for the Administrative Services Office (William Gee, Chief), responsible for travel arrangements, duplicating services, word processing and maintaining the switchboard.

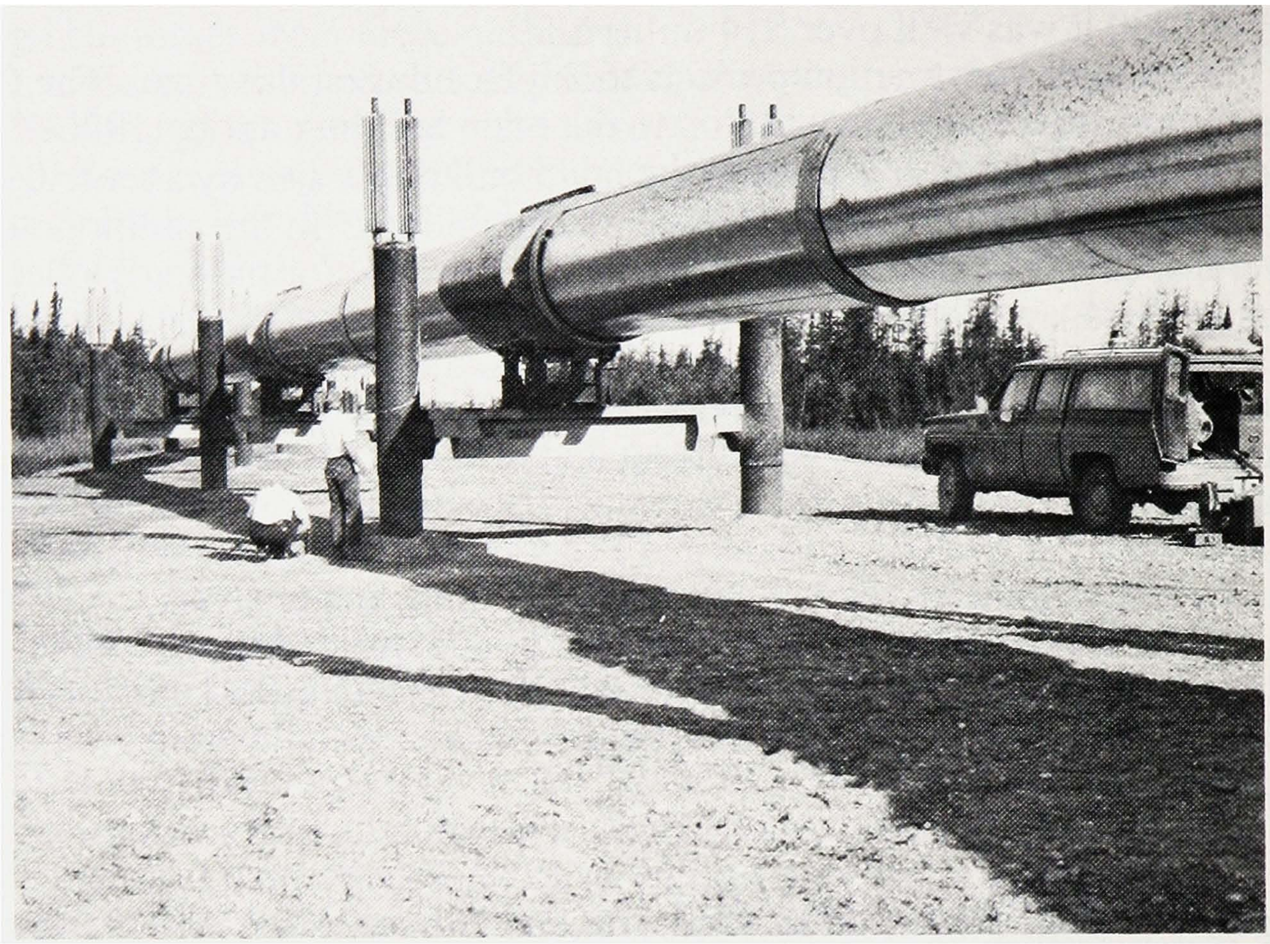
The other major addition to CRREL's research facilities was the completion of the Ice Engineering Facility in 1978. The research laboratory, the largest and most modern of its kind, was designed to enable research personnel to conduct large-scale studies of ice and its effects in a controlled refrigerated environment. The 210- by 160-ft, two story facility was constructed to contain three major refrigerated areas—an 80- by 160-ft modeling room, a flume room and a test basin.

During this period CRREL's research accomplishments were equally impressive. CRREL's expertise and technical information helped to bring the successful completion of the trans-Alaska oil pipeline in 1978, surely one of America's greatest engineering achievements. And CRREL biologists and soil scientists closely observed the pipeline's impact on the Alaskan landscape, helping to assure the preservation of Alaska's natural environment.

Work on the trans-Alaska pipeline brought two Army Research and Development Awards to CRREL employees. In 1976, a CRREL research team consisting of Dr. Pieter Hoekstra, Paul Sellmann, Dr. Steven Arcone and Allan Delaney won the Research and Development Award for their work in developing techniques for subsurface geophysical exploration. Some of this work involved finding grounding areas for the pipeline's cathodic anti-corrosion system, a project that saved the pipeline builders well over $1 million, as well as demonstrating the practicality of this experimental technique.

In 1979, Frederick Crory won an Army Research and Development Award for his advice in the construction of the pipeline. Crory, an expert on pile foundations in permafrost, was recognized in the citation as having played "a key role in the successful design and construction of this major engineering project."

In this 5-year period, CRREL researchers also received two other of the prestigious Research and Development Awards. In 1976, Dr. Malcolm



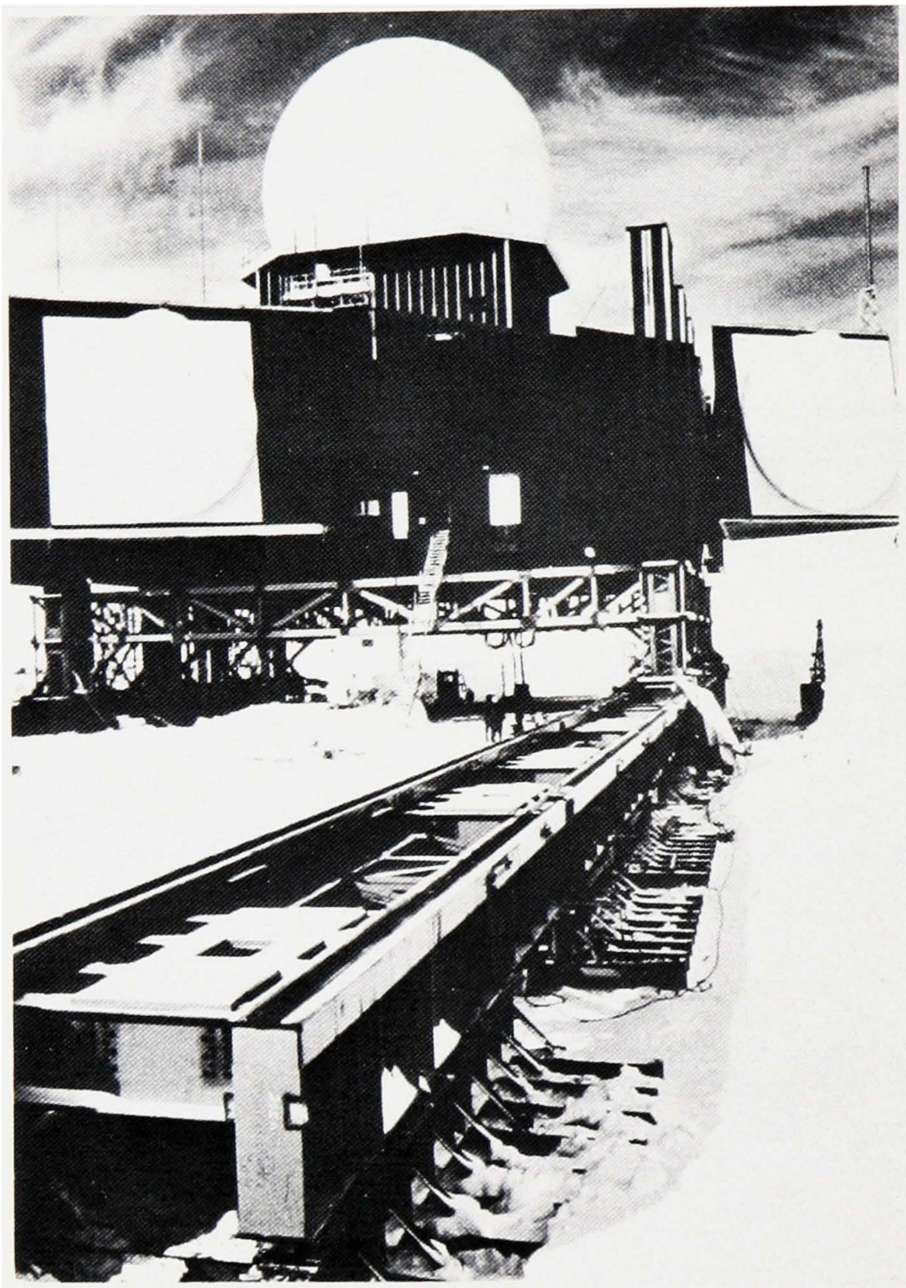
CRREL researchers monitoring temperatures of thermal piles on trans-Alaska pipeline.

Early geophysics device.

Large saw used to cut ice from lock walls at Sault Ste. Marie, Michigan.

Mellor received one of these awards for his years of research in the excavating and blasting of snow, ice and frozen ground. Some applications of his work were the development of machines for the rapid excavation of frozen ground and for cutting ice from lock walls, and the controlled blasting of a large ice wall in Antarctica to provide a pier for the docking of supply ships.

Wayne Tobiasson's 1977 Research and Development Award was for a single project that he conceived, designed and helped to supervise, the moving of a 10-story-high, 3300-ton Distant Early Warning (DEW) Line facility on the Greenland Ice Cap. The foundation of the radar facility had been weakened by the accumulating snow and shifting glacial ice so that it appeared that a new structure would need to be built. But by moving the existing structure onto a new foundation, the government saved an estimated $1.5 million.



DYE-3 move.

CRREL received a number of other awards during the late 1970's as well. Perhaps the most significant individual honor was the election of Dr. Wilford Weeks to the National Academy of Engineering, the highest professional distinction that can be conferred in the field of engineering. Dr. Weeks, a former president of the International Glaciological Society, was cited for the "application of research on the strength properties of sea ice to the engineering problems encountered in arctic waters." Week's work on sea ice has, of course, been extremely important to oil exploration activities in Prudhoe Bay and others areas off the coast of northern Alaska.

In addition, Rodney Poland, Executive Assistant at CRREL nearly from its inception, won an Army Decoration for Exceptional Civilian Service in 1978. He was cited for his exceptional accomplishments in his administrative duties at CRREL.

Yet probably the most important awards received by CRREL during this period were awarded to the laboratory as a whole. In recognition of CRREL's support of the Army and its mission in fiscal year 1978, CRREL was awarded the Army Special Award for Accomplishment in a presentation

Coring multi-year ridge just northwest of Reindeer Island, offshore of Prudhoe Bay, Alaska.

Spraying lock wall with icephobic coating developed by CRREL, Sault Ste. Marie, Michigan.

Air-transportable shelter for Arctic use.

by the Assistant Secretary of the Army for Research, Development and Acquisition. Among the achievements noted in the award citation were the major accomplishments of the Land Treatment Research and Development Program and the many accomplishments of the ice engineering program—in particular the development of various techniques to keep navigation locks free from ice.

In recognition of its achievements during fiscal year 1979, CRREL received the U.S. Army Award for Excellence in a presentation by Lieutenant General Bratton, Chief of Engineers. Accomplishments noted at the award ceremony included the onset of the operation of the Ice Engineering Facility, the development of a model of the ice accretion process for helicopter rotor blades, research on the properties of snow, development of nondestructive techniques for detecting moisture in roofs, and design and construction of an air-transportable shelter for arctic use.

Yet, a number of CRREL's somewhat smaller projects also received national attention during this time. One was a proposal by Dr. Wilford Weeks for towing icebergs from Antarctica to Australia and South America to provide fresh water for irrigation. This idea eventually led to the First International Conference on Iceberg Utilization in 1977.

Also in 1977 and 1978 CRREL researchers were involved in the Ross Ice Shelf Project which also received extensive media coverage. Although the CRREL coring drill became trapped in the shifting glacial ice, a thermal drill, developed by Browning Engineering of Hanover, New Hampshire, and tested at CRREL, succeeded in making a large hole through the 1400-ft ice shelf to reach the sea below. This allowed research scientists to lower such devices as a television camera, bait bottles, thermometers, plankton nets and coring devices. These instruments detected, for the first time, biological activity in the sunless environment beneath the Ross Ice Shelf.

However, the events of the 1975-79 period were not all positive. In 1976 occurred the only fatal accident in CRREL's history. The accident happened while a 21-year-old Northeastern University engineering student, Gordon W. Dow, was operating a coring auger to obtain pavement core samples. No-one witnessed the accident, but his arm apparently had been caught in the motorized auger, and despite rapid emergency efforts by several members of the CRREL staff, he died soon after arrival at Hanover's hospital. This accident was extensively investigated and led to greater precautions to ensure that such a tragedy would never recur.

Another problem of the 1970's was a temporary slow-down in the scientific exchanges between the U.S.S.R. and the United States because of a worsening of international tensions. However, these exchanges soon were back in force, and a Soviet scientist, Igor Zotikov, spent several weeks at CRREL in cooperative research in 1979.

CRREL changed commanders in July 1978 when Lieutenant Colonel Alfred Devereaux succeeded Colonel Crosby, who had been at CRREL for 5 years. Devereaux, who held a doctorate from Ohio State University, had previously been Deputy Commander of the Engineer Topographic Laboratory at Fort Belvoir, Virginia. Crosby went to work for the North Pacific Division of the Corps of Engineers as Deputy Division Engineer.

1980-85

Some of the major accomplishments during the early 1980's were the completion of the Land Treatment Research and Development Program and the publication of the results of the U.S. Tundra Biome Research Program. In regard to the trans-Alaska pipeline, CRREL continued to monitor both the pipeline itself and the haul road next to the pipeline for their long-term performance.

CRREL also underwent some administrative changes at this time. In 1980 a new branch, the Geophysical Research Branch, was created in the Research Division, and headed for more than two years by George Aitken and then by Dr. George Ashton. At the same time, the Physical Sciences Branch was dissolved, with many of its members going to the new branch.

One of the 1981 Army Research and Development Awards was presented to Dr. George Ashton for his work on the thermal processes that determine the behavior of river and lake ice. In particular his research had developed methods to perfect the technique of using air bubbler systems to melt ice covers. He also developed a computerized technique for predict-

Laser beam defraction.

ing the effect of heated water discharges on the thermal regimes of water bodies.

In July of 1981, Colonel Wayne A. Hanson succeeded Colonel Devereaux. Hanson, a registered professional engineer, previously was the material test director for the Cold Regions Test Center at Fort Greely, Alaska. He stayed at CRREL for a little less than 2 years, until May 1983.

Also in 1981, Dr. Dean Freitag, who had been CRREL's Technical Director since 1972 retired to become a professor of engineering at Tennessee Technological University. Dr. Lloyd Breslau, former director of the Coast Guard Research and Development Center, succeeded Freitag as Technical Director.

CRREL's research programs during this period continued to expand. New programs included the SNOW-ONE, SNOW-ONE-A, and SNOW-TWO projects held at Fort Ethan Allen, Vermont, and Grayling, Michigan. These three projects involved testing a number of electromagnetic and optical sensing systems in the winter environment. CRREL researchers, primarily from the Geophysical Research Branch, collected meteorological data and coordinated the various research efforts of many participating agencies during these tests. The River Ice Management (RIM) program, whose purpose is to increase the navigation period on inland waterways, also started in the mid-1980's.

On 16 September 1981, CRREL officially recognized its 20th birthday with a celebration held in the large work area of the Ice Engineering Facility. All the current CRREL employees were joined by dozens of retired employees at a luncheon. In a short statement on the 20th birthday program, Colonel Hansen said the following:

"CRREL, as a Corps of Engineers Laboratory, can be proud of its contributions and accomplishments over the period from 1961 to 1981. It has maintained its leadership in cold regions research despite being shifted from one major command to another and going through a period where military interest was focused on the tropical environment. It has been possible for CRREL to not only survive but grow because of the high quality people associated with the organization now and in the past. Quality products and internationally recognized professionals have established the laboratory as a mecca for cold regions researchers.

"With the increased emphasis on natural resource development in the Arctic, CRREL's developed technology and research will become even more important. This provides new opportunities for service to the Corps, the Army and the Nation. Happy Birthday CRREL."

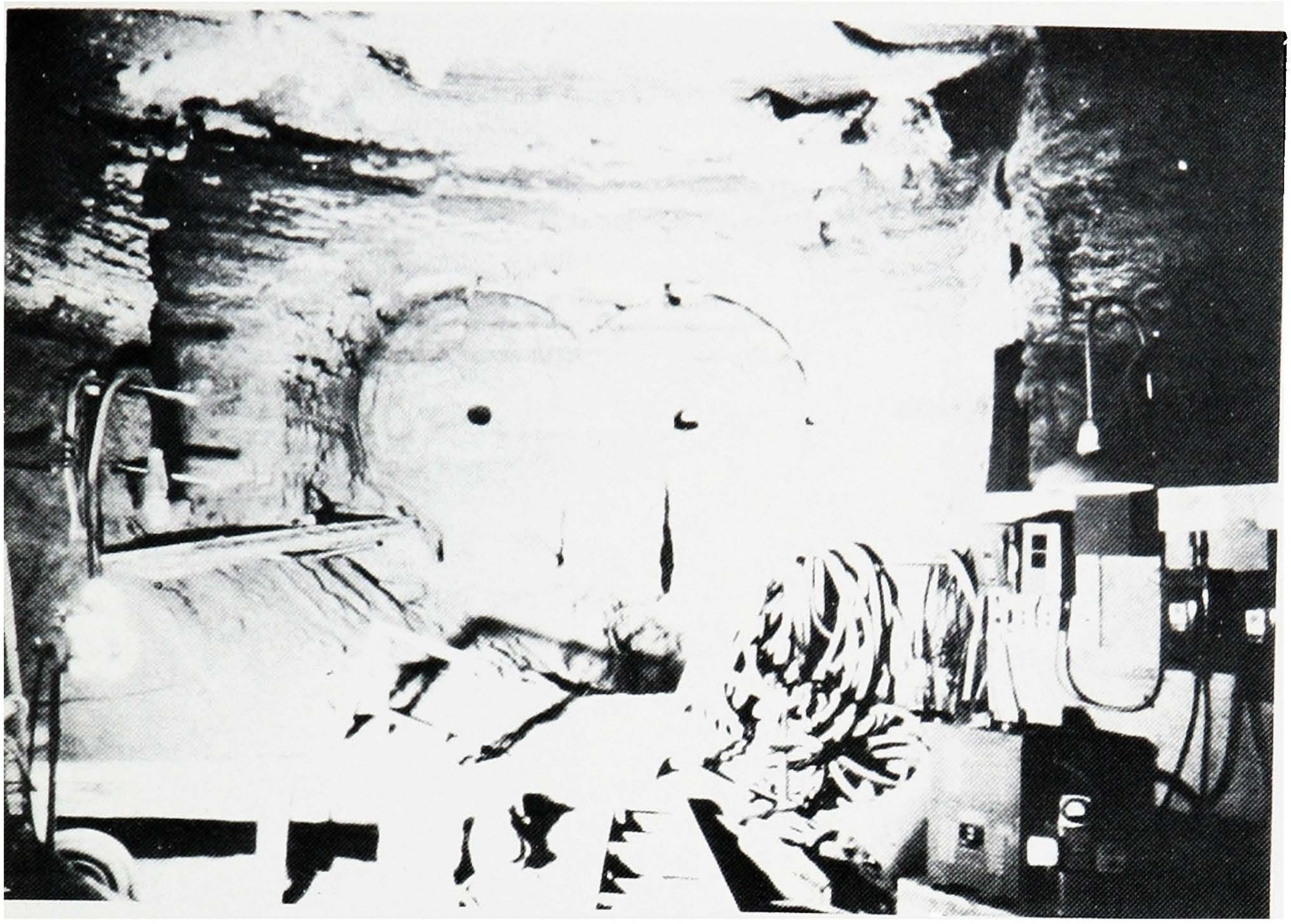
A significant development in the late 1970's and early 1980's was the opening of an exchange of scientific information between CRREL and the Institute of Glaciology and Cryopedology in the People's Republic of China. This exchange began in the fall of 1978 when two CRREL re-

J. Brown and Y.-C. Yen at Chinese Permafrost Conference.

searchers participated in a $2^1/2$ week seminar tour on cold regions engineering and construction, just before the official recognition of China by the United States. In 1981, CRREL participated in the Second National Chinese Conference on Permafrost, and the following year a Chinese researcher began a 2-year sabbatical at CRREL to learn about new techniques for analyzing frozen ground. This exchange opened a much wider participation by Chinese scientists in international exchanges of information on cold regions science.

At almost the same time as the Chinese Permafrost Conference, two other CRREL scientists participated in a joint American-Soviet expedition into the ice-covered Weddell Sea of Antarctica aboard the *Mikhail Somov*, a Soviet ice-breaking transport ship. Along with 22 other American and Soviet scientists, the CRREL researchers spent nearly $3^1/2$ weeks within the frozen sea. One of the purposes of the voyage was to study the polyna, a large area of open water surrounded by ice, which often forms in the Weddell Sea. Although no polyna formed during the time of the voyage, the re-

Launching meteorological balloon from Mikail Somov.



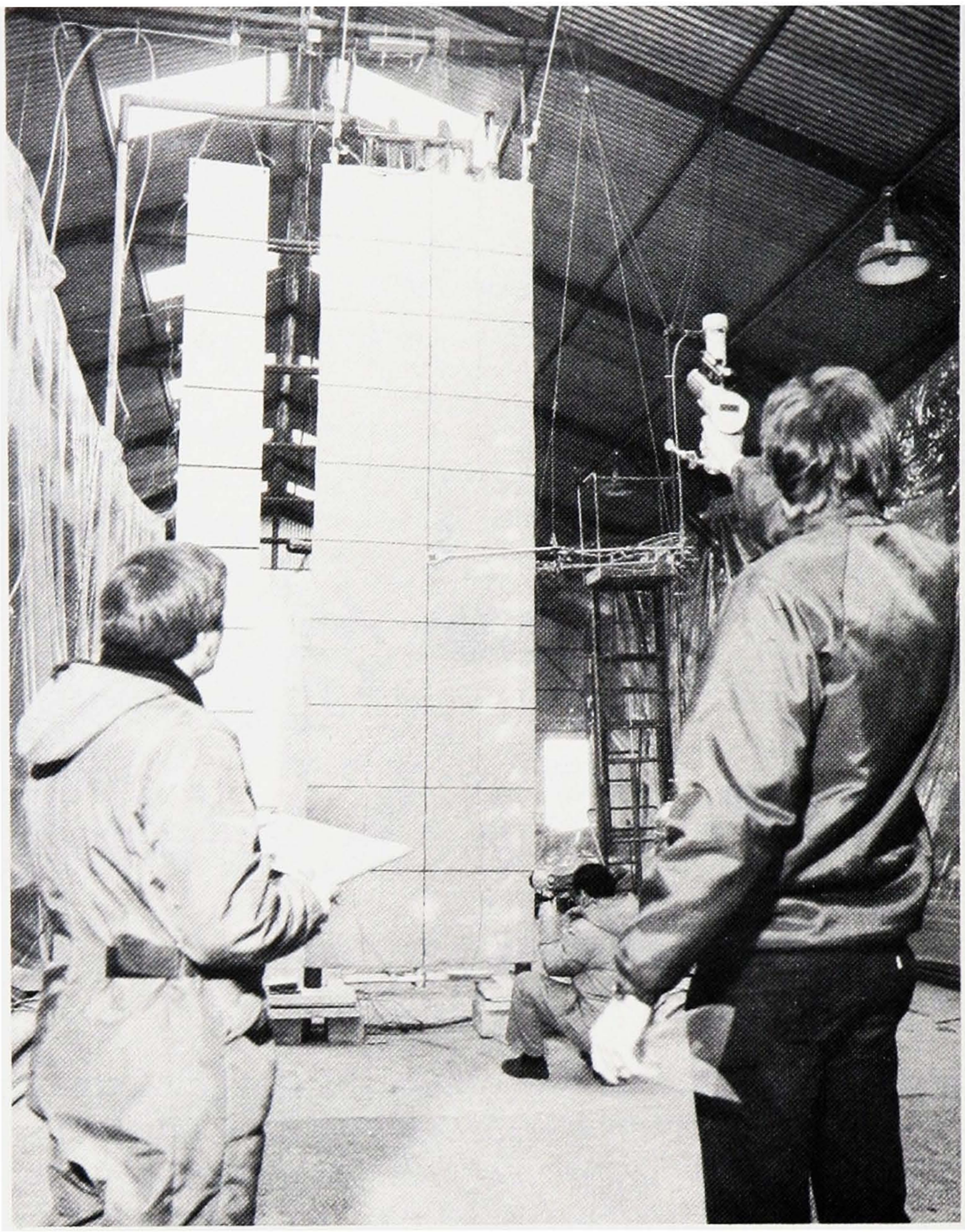
Permafrost tunnel, Fox, Alaska.

searchers onboard the *Mikhail Somov* obtained a wealth of new data about Antarctic sea ice, ice pack extent and meteorological conditions.

CRREL personnel also played a key role in the Fourth International Conference on Permafrost, held in Fairbanks, Alaska, in 1983. In addition, a number of major symposia have been held at CRREL (in Hanover) in recent years. These include the Eastern Snow Conference, the SNOW Symposia, the Third International Symposium on Ground Freezing, a conference on icing, and a workshop on ice penetration. These have all been coordinated by CRREL's Public Affairs Office.

Among CRREL's more notable projects during this time was an extensive study of sea ice off the northern coast of Alaska funded primarily by the Shell Development Company. This study was primarily concerned with the mechanical properties of ice samples from the large pressure ridges (mounds of sea ice fragments that result from crushing of interacting plates).

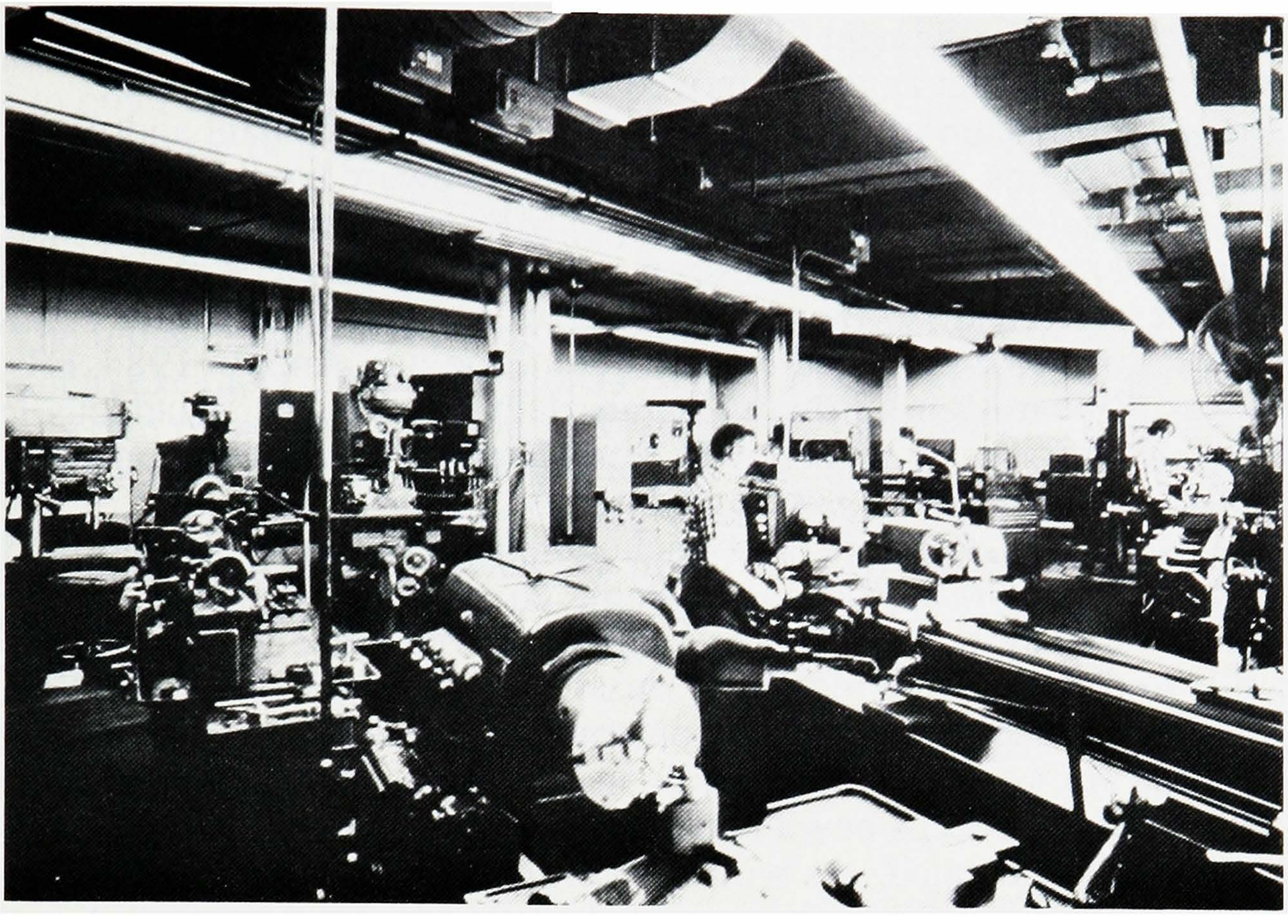
Another important project was in predicting the amount of ice that would form on the tank containing the supercooled fuel for the launcher of the Air Force Space Shuttle. This new shuttle is to be launched from Vandenberg Air Force Base, in a climate significantly colder than that of Cape Canaveral, Florida. The CRREL study predicted the amounts of icing to be expected and suggested ways of minimizing the icing. The research approach used by CRREL researchers to study this icing problem was estimated to have saved the Air Force at least $500,000 over the costs of a more conventional approach. For this work Michael Ferrick received an Army Research and Development Award in 1983.



Testing cryogenic panel (for the Space Shuttle) at CRREL.

The CRREL activity to gain the most attention during this time was not a research activity but an application of this research. When an Air Florida airliner crashed into the Potomac River on 14 January 1982, CRREL researchers Arnold Dean and Carl Martinson were able to locate the "black boxes" (containing the flight and voice recorders) beneath the ice-clogged river by using a broadband subsurface radar that they had developed to profile frozen rivers. They also were able to locate bodies and parts of the wreckage and thus to help with the effort to determine the cause of the crash. Again CRREL researchers succeeded in rapidly solving a cold regions problem beyond the capabilities of other organizations.

In 1982, the Technical Services Division (Ronald Atkins, Chief), was reorganized, being divided into the Technical Information Branch, the Engineering and Measurement Services Branch and Facilities Engineering. The Technical Information Branch (Wesley Pietkiewicz, Chief), has been responsible for editing and publishing over a thousand CRREL technical reports and information bulletins since CRREL was founded. Also, this



CRREL machine shop.

branch contains the CRREL library and one of the largest cold regions collections in the world. It maintains the *Bibliography on Cold Regions Science and Technology*, with more than 100,000 publications accessioned to date.

The Engineering and Measurement Services Branch (Donald Garfield, Chief), is responsible for developing and maintaining much of the specialized equipment used by the laboratory. Engineers and instrument makers from this branch developed the drills used in Greenland, Antarctica and Alaska for geological investigations. Sophisticated computer-operated meteorological sensors are some of the other instruments made here. The branch also maintains CRREL's central computer and provides programming services for the research staff. Facilities Engineering (David Gaskin, Chief) maintains the physical plant of CRREL. This includes not only care of the five major buildings and CRREL's vehicles but also of the sophisticated refrigeration systems in the main coldroom complex, the Ice Engineering Facility and the new Frost Effects Research Facility.

In 1983, Colonel Morton Roth, from the Defense Mapping Agency, Inter-American Geodetic Survey, Fort Sam Houston, Texas, took command, and CRREL has continued to prosper. In a period when the Corps is enlarging its National role as the Federal Engineer, CRREL has sought to broaden its activities into new areas of cold regions research and development.

In 1983, CRREL's personnel office was consolidated with that of the New England Division of the Corps of Engineers. The greatly enlarged Personnel Office (David Wilber, Chief), now is responsible for recruit-

ment, training and appraisal of more then 900 employees. At the same time, the Resource Management Office (Peter Swart, Chief), responsible for accounting and budget analysis, moved into new offices.

A research team of Yoshisuke Nakano, Joseph Oliphant and Allan Tice won a 1983 Army Research and Development award for their research in the use of nuclear magnetic resonance (NMR) techniques for investigating water content and transport in frozen soils, and David Deck received an Army Research and Development award for designing a frazil ice control structure for a town plagued by recurrent flooding. And, in 1984, Edgar Andreas, Richard Berg, Edwin Chamberlain, David Cole, Thaddeus Johnson and Walter Tucker all received Army Research and Development awards for their research accomplishments.

Also in 1984, CRREL personnel completed their survey reports for 31 sites of the new North Warning System, to replace the aging DEW line. The new radar system will have greatly improved radar coverage, and will be able to detect low-flying cruise missiles as well as ICBM's and bombers. CRREL personnel evaluated the construction and access problems of each site, while Air Force personnel evaluated the range of the radar equipment.

In 1985, CRREL's new Frost Effects Research Facility was completed and officially dedicated. As with the addition of other research facilities, the specialized laboratory greatly expanded CRREL's research capabilities. In the \$6 million, 29,000-ft^2 building, CRREL scientists and engineers are able to study frost heave and permafrost problems in a controlled setting. This research facility is the only one of its type in the United States, and is

CRREL site selection team locating new radar stations along Labrador coast, July 1984.

considered to be superior in its capabilities to similar frost research laboratories in other countries.

Construction of a new coldroom complex for CRREL also began in 1985. When completed, the new coldrooms will offer researchers state-of-the-art refrigeration capabilities and the system will no longer use the dangerous TCE refrigerant.

The replacement can be seen as symbolic of CRREL's continuing commitment to excellence in cold regions research and development. CRREL has helped to pioneer this Nation's expansion into northern Alaska and the study of the cold regions, and now CRREL is helping to improve on this earlier scientific and engineering work. Undoubtedly the next 25 years will bring forth an even greater advancement in CRREL's involvement with research and development in the areas of the world affected by snow, ice and frozen ground.